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ELECTRIC LIGHTING IN MILLS.

By C. J. H. WOODBURY.

[Read before the New England Cotton Manufacturers' Association, Oct. 25, 1882.]

Although the cruder forms of electric light were made early in this century, preceding the locomotive, the telegraph and illuminating gas, yet the mechanical refinements devised within a few years have been necessary to master many of the practical and economic difficulties, and render it feasible to bring electric lighting from the laboratory to the commercial world, creating an element in manufacturing affairs.

Although our object is to consider electric lighting solely in regard to its employment for industrial purposes, a better understanding may be reached by examining some of the principles involved in its production.

The accumulation of electricity by means of a dynamo machine is based upon two principles: First, that when a wire is moved across a magnet through the field of force, the power exerted against the attraction of the magnet is converted into electricity. Second, when an electric current is passed through insulated wires coiled around a piece of iron, the iron is magnetized.

In a dynamo machine the magnets are very feebly magnetized; but when the armature is revolved it generates an electric current, which

passes through the wires around the magnets, increasing their strength and enabling them to produce a stronger current in the armature, and this in turn adds to the strength of the magnets, the armature and the magnets reacting on each other until the limit of the capacity of the magnets is reached, after several hundred revolutions of the armature. When the motion of the armature is stopped the magnets lose nearly all their magnetism, as soft iron will not retain magnetism like steel.

Permanent steel magnets were originally used for this purpose; but electro magnets are capable of holding twenty times as much magnetism as permanent magnets.

This is the rough outline of dynamo machines. Their construction is not so simple a matter, involving numerous problems upon matters which cannot be considered here.

Electricity for lighting might be furnished by galvanic batteries, but the cost would amount to twenty-five times as much as when generated by a dynamo.

There are two methods of converting electricity into light. The arc light is chiefly due to the glowing of the tips of the carbons caused by the high temperature produced by the current overcoming the resistance offered by the space between the carbon poles, whereby the energy of the electricity is converted into heat.

The carbons are slowly volatilized and partially burned. The intensely heated vapor adds to the illumination, but the combustion of the burning carbon interferes with the light, as the arc light is more brilliant when enclosed in a glass receiver and removing the air. The incandescent light is produced by the current overcoming the resistance offered by a filament of carbon and raising it to a temperature sufficient to render it luminous.

The immediate destruction of the carbon is prevented by regulating the quantity of the current and enclosing the carbon in a glass bulb and exhausting the air, so that it cannot burn.

Both the arc and the incandescent light is due to the glowing of intensely heated carbon. In the arc light the incandescence is destructive to the carbon; and in the incandescent lamp the object is to make the carbon as enduring as possible under the conditions of brilliancy, which are essential for satisfactory results. The arc lamps are placed at openings in the conducting wires, and the carbons form a portion of the circuit. The electricity passes through the lamps in order, and the tension is reduced a certain amount at each lamp.

In the incandescent system the lamps are hung in wires swung down from the main conductors, so that the current is divided, an equal portion passing through each lamp. The comparison is sometimes made that the main conductors could be represented by the sides of a ladder, while the position of incandescent lamps would be in the middle of the rounds of the ladder.

In the arc light, where the carbon is heated to destruction, the total quantity of light for a given expenditure of electricity is about nine times what it is in an incandescent light working at a commercial rate. In an incandescent lamp the question of endurance of the carbon is the second factor in determining the most advisable brilliancy for the light.

According to Howell's experiments on the Edison light, if the electricity supplied to a 16 candle power Edison lamp be increased one-fourth, the candle power is doubled, but the endurance of the lamp would be reduced.

The golden mean of the true economy between expense of renewals of lamps and that of power can be reached only by long experience.

I presume that the present intensity of brilliancy which has been adopted is at about the minimum cost for the present construction of carbons.

The unit of measurement of light is expressed in candle power, which is the light furnished by a standard wax candle burning 120 grains per hour. The candle power of burning gas is the light given by an argand burner consuming 5 cubic feet of gas per hour.

With the incandescent lamp the light is nearly uniform in all directions.

In the arc light the terminals of the carbons are different, the lower carbon consuming to a sharp point, and the upper one is blunt and the end concave. The light emitted from these ends is not alike; the upper carbon having the most heated surface, about nine-tenths of the light is thrown downward below a horizontal plane. The power of arc lights, as generally stated, is that of the strongest rays which are thrown down at an angle of 45 degrees, which is about twice the brilliancy of the average light. Nearly half of the light is held back by the white glass shades, and the arc lights being further apart an excess of light is necessary to secure sufficient diffusion at extreme points, because the intensity of light diminishes as the square of the distance.

The value of electricity for lighting mills is based upon the charac-

ter of the illumination desired, each mill being, to some extent, a law unto itself.

One of the first items of consideration is the influence of electric light upon the opertive, considered as a machine to be kept in good condition, in order to obtain the best results. As the electric light does not require any air to support combustion, it does not injure the air in a mill.

On the other hand, Dr. William A. Hammond states:* "A gas burner consuming four cubic feet per hour produces more carbonic acid gas in a given time than is evolved from the respiration of eight adult human beings."

This is an important matter in night work, when the air becomes so impure that it prevents the operatives from doing the amount of work which they could do if the air was pure.

Gas lights increase the temperature excessively. In the basement story of a mill 400 by 65 feet, and 15 feet high, were 456 looms on heavy colored cotton goods. The room was lighted by 457 four-foot gas burners. When these were used it was stated that the temperature increased 25 degrees in an hour. Now the room is lighted by 35 electric lights, and the increase in temperature, if any, is not enough to be indicated by an ordinary thermometer. In two other mills the rise in temperature, after lighting the gas, varied from 11 to 13 degrees.

The economy of any light increases much more rapidly than the temperature. A large gas light furnishes more light for a given quantity of gas than a small one.

† Nine years ago I made some experiments upon the efficiency of kerosene burners, and obtained similar results.

The temperature of the upper carbon ‡ in an electric arc light is estimated at 6000 degrees Fahrenheit, and the lower one at 4500 degrees, but this estimate refers only to the special light experimented with, which were used small carbons, and the general result to-day is probably greater than the one given above.

This high temperature furnishes much more light rays from a given amount of heat than a lower temperature would give.

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* *Our Continent,* March 8, 1882.

† Journal Franklin Institute, August, 1873.

‡ *Journal de Physique,* August, 1879.

Dr. Chas. W. Siemens, in an address delivered before the British Association in York, England, last August,* stated that in a gas burner only one per cent. of the calorific energy of combustion produced light; while in the incandescent light it was three and seven-tenths per cent., and in the arc light it amounted to thirty-three per cent. Whether subsequent investigation may not modify these results is an open question, but the general statement that the electric light contains a much smaller proportion of the heat rays than gas will be questioned.

It is stated by Mr. W. H. Pickering † that the injurious effects of artificial light upon the eyesight are due to heat from lights, and not to the light itself.

Another matter of value in electric lights is the ability to distinguish tints. The light from the tips of the carbons is white, and the light of the arc between them is a bluish-purple, so that the general tint of the arc is that bluish-white, which has a very white appearance.

Where the use of shades of color is involved, electricity furnishes the only artificial light which can be feasibly used; and in such cases where the operation of a certain department would otherwise be limited to the duration of sunlight, the economy from the use of the electric light is, to a certain extent, proportionate to extra profits accruing from this extension of the time of labor.

In other departments of manufacturing, the aid to the production of perfect work, by this improved illumination, is a source of additional revenue, because the proportion of damaged goods usually made when the mill is badly lighted is thereby diminished.

Expense.

The cost of maintenance of a system of lighting bears little relation to its intrinsic worth. The item of cost of lighting is a small fraction of the whole operating expense, and what is desired is to light a mill so well that there will be no difference in the character of day and night work, either in quantity or quality. Any expenditure beyond that is unwarrantable.

The question of the cost of lighting by electricity is subject to many legitimate variations, of which the question of power is most variable.

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* *Engineering*, September 1, 1882.

† *Nature*, February 9, 1882.

In a steam mill, where the dynamo is driven by the same engine that runs the mill, it should only be charged with its share of fuel, but not with any other expense of power, wherever it does not introduce any new expenditures in the way of plant, repairs, or labor in the engine room.

Some mills have departments which are only run by daylight, where work is thrown off at sundown, and so compensates for the steam required by the dynamo. For example, in one mill using electric lights, the power used in the nepping room is slightly more than is required for the dynamo, so when the machinery in that room is stopped, the dynamo can be started without bringing any extra load on the engine. Most factories are driven by water power, with supplementary steam power during low water in the summer months; the electric lights would be required during the shorter days of the year at a time when there is usually an abundance of water, and the extra power can be used by the dynamo by the use of more water, without requiring any additional expense.

It is difficult to make a comparison between various methods of illumination, because a change of light is always made an excuse for more light.

The majority of mills are lighted with gas made by the destructive distillation of petroleum, and of about 80 candle power, which is generally reduced to 60 candle power by mixing air with it, and burned through one foot (nominal) burners, which consume about one and a quarter feet per hour.

The annual cost of oil gas per burner is from seventy-five cents to one dollar. In all these estimates, interest at six per cent. forms one item in cost. One large corporation, with exceptional privileges, makes its coal gas at an annual cost of 69 cents per burner. Another corporation, inland, makes its coal gas at $1.25 per thousand cubic feet, at an annual cost of $1.79 per burner, each burner consuming 1433 cubic feet annually.

Of two large mills in the same city, manufacturing similar goods, the more modern one makes oil gas at an annual cost of 79 cents per burner, while the older one buys coal gas at $2.65 per burner.

Sometimes when the gas making apparatus is not managed with skill, the goods are damaged from soot which settles on them.

The longer time light is required, the average cost is lessened, because with the addition of operating expenses, the interest on plant, being a fixed amount, becomes a smaller proportion of the whole cost.

In electric lighting, the cost of plant is so much that interest is an important item, and when a mill is run nights, the relative cost of electric lighting is materially diminished. A white cotton mill, running 60 hours a week, generally uses light 300 to 350 hours a year; where they run 66 hours a week lights are required 400 to 450 hours a year. A dark mill requires about twice the number of lights that is sufficient in a white mill, and uses light about 100 hours a year more than a white mill.

An arc light, as generally used in mills, requires about one horse-power. Mr. James Renfrew, Jr., at Adams, Mass., has found, by test, that the 40 light Brush dynamos in his mills each require 36·6 horse power. The lights were running in a satisfactory manner, but no photometric tests were made.

The cost of arc lights in several steam mills running 400 hours per year, is 6½ cents per hour, of which 1½ cents are for carbons, and 5 cents for attendance, coal, depreciation and interest. When a mill runs nights, the hourly cost is diminished.

The ratio of substituting electric lights for gas, is quite variable, being one arc light to from ten to twenty gas burners. In one mill lighted by kerosene the ratio was one arc lamp to eight kerosene lamps.

In a colored mill, one arc light will light the looms on 700 to 1400 square feet of floor, but in a white mill the same light will be sufficient for looms on 1000 to 2000 square feet of floor. The reflected light from white walls and ceilings adds very materially to the diffusion.

A card room 48 by 100 feet, containing 64 cards, was satisfactorily lighted by one arc light. The end of the room was extended about 40 feet, and the light was not satisfactory toward that end of the room, because there was no end wall to serve as a reflector.

It is convenient to compare the cost of electric lighting with the expense of gas in the same place, although it must be remembered that gas does not furnish as much or as good light, and is therefore not so valuable where quality of light is of importance.

In a weave room, on very fine work, 24 arc lights replaced 292 six foot burners, which consume (292×6) 1752 feet per hour, so one arc light represents the consumption of (1752÷24) 73 feet of gas per hour. A careful estimate shows these arc lights to be costing 6½ cents an hour, so this arc lighting system represents gas at 89 cents per thousand. A similar estimate in another mill gives the annual cost of gas

$2188, and electricity at $1125, or equal to gas at 90 cents a thousand. The annual saving to that mill in lighting expenses by the use of electricity makes a profit of $1603, which represents 6 per cent. on $17,716, without making mention of any improvement in work or production due to that light. In both of these establishments the lights were used about 450 hours per year. Other estimates give the cost of arc lighting equal to gas at from 65 cents upward per thousand. In the case of incandescent lighting the cost is more difficult to estimate, because they are run at all degrees of brilliancy, affecting both the power and the life of the lamp.

Both the Edison and the Maxim lamps are guaranteed to average 600 hours; yet in the New York post office the average record of the Maxim lamps is stated to be 1850 hours up to September first, and 15 lamps had already burned 3456 hours.

The ferry boat Jersey City, belonging to the Pennsylvania Railroad, is lighted by the Maxim lights, and their record has been given to me as averaging 1645 hours, and the lamps still burning.

The data for the above was taken with lamps in use, and does not represent their ultimate endurance.

Mr. Timothy Merrick, of Holyoke, authorizes me to give the facts respecting his experience with the Edison system in the Merrick Thread Company's mill, number 3. This mill runs all night five nights in the week for fifty-one weeks per year, using light 2869 hours per annum. It was lighted by 95 burners with city gas, costing $2.13 net, which amounted to $225 per month. 95 Edison B burners (8 candle power) were substituted for the gas. In the first 1000 hours five lamp carbons had broken, and October 20th they had been in use 1278 hours, and 11 had broken.

Allowing that the lamps average six months' use, the cost of lighting is made up as follows:

190 lamps, at $1, . . .	$190 00
Interest and depreciation, . .	153 50
6 h. p., at $10, ...	60 00
Annual cost Edison light, . .	$403 50
Monthly " " . . .	33 62
Monthly cost gas, . . .	225 00

The results from these lamps are very satisfactory, and certainly in

excess of what would have been obtained if the lamps had been forced beyond their normal capacity.

The Holyoke Water Power Company furnish water power very cheaply; and the result may be interesting if we hold the Edison Company to their minimum guarantee; and also charge the dynamo with four pounds of coal per hourly horse power.

4·78-100 renewals of 95 lamps equals 454 lamps, at $1.00,	$454.00
Interest and depreciation, ...	153.50
30·74 tons coal, at $5.75, . . .	176.81
Annual cost Edison light, ...	$784.31
Monthly " " " . . .	65.36

Which is equal to gas at 65 cents per thousand.

The mill is situated at the base of a high bank, and is only eleven feet, six inches between floors, so it is very hot in summer, and Mr. Merrick informed me that it would have been impossible to run the mill nights during the extremely hot season last summer, if the help had been subjected to the heat and vitiated air from the burning gas.

It must be kept in mind that an instance of a mill running day and night is an extreme one in favor of the electric lights; but the data are given and the matter can be estimated to suit other times of operation.

If these electric plants were charged the proportionate cost of power, besides coal, the cost would be estimated greater than stated above.

Improvements.

The question is frequently asked, will there not be improvements in electric apparatus, so that the light will be furnished for less cost and power. Of course there will be improvements, but it seems as if they would refer to attachments rather than the more permanent portion of the apparatus. The dynamo machines are the most perfect instruments, as they convert 80 to 90 per cent. of the motive power into electricity delivered at the conducting wires. It will be found essential that all dynamos have current governors which regulate the supply of electricity in proportion to the demand, without waste of energy.

There does not seem to be any demand for a change in the system of wiring.

In the arc lamps there is urgent need of better carbons, and in the incandescent lamp there is a demand for the highest qualities of endurance and electrical resistance.

These are all matters of detail, and except the first, refer to portions which are subject to continual renewal.

The so called "storage" of electricity is a subject which is the object of much interest. Electricity alone, of all forms of energy, is used from hand to mouth, so that the dynamo must be equal to the greatest demand upon the system at any one instant.

All forms of electric lights require uniformity in the speed of the dynamo and the incandescent lights are especially sensitive to variations in the speed, so that it is frequently advisable to have a separate engine solely on that account. Such uniform speed would not be essential for the dynamo used in charging secondary batteries.

In a storage battery, the electricity is not accumulated in any manner, as is sometimes assumed, but a certain chemical action is produced by passing an electric current through the battery, and later on a counter-chemical action produces electricity, when the battery is discharged.

The Faure storage battery consists of sheets of lead, coated with red-lead and covered with sheets of felt. The whole is enclosed in a box, and covered with dilute sulphuric acid. On passing an electric current through the battery, the red-lead on the negative side loses its oxygen, which combines with the red-lead on the positive side, the result being that one coating of red-lead is reduced to pure lead, and the other side changed to peroxide of lead. When the battery is put in use, the theory is that this atom of oxygen leaves the peroxide of lead on one side, and rejoins the spongy lead on the other side, producing the secondary current; but difficulty has been experienced from losses due to various kinds of local action in the battery, such as the deposition of sulphate of lead, and the injury to the sheets of felt, so that the electricity regained has not been as much as is desired.

There are several forms of secondary batteries, all of which are similar in principle; and one free from the faults due to local action would be a great boon to all users of incandescent lamps, for then the apparatus would be permanent, and its efficiency such that would insure commercial success.

Safeguards of Electric Lighting.

The experience of the insurance companies, in regard to electric lighting, has constituted the subject a factor in underwriting. It is difficult to estimate the amount of hazard to which property is sub-

jected by its use, because the elements of danger are diminished by suitable precautions. The hazards attending the use of the electric light have been over-estimated; not in numbers or magnitude, but because too little account has been given to the preventable nature of such occurrences. If these precautions are disregarded, only good luck will avert disaster.

It is sometimes assumed by those ignorant of the facts that electric lighting apparatus cannot set a fire. Electricity is no exception to other forms of energy. All power can be converted into heat.

Your mills are equally liable to hot bearings, whether the motive power is derived from the fires under the boilers, or to the head of water in the mill pond.

Whenever anyone states, as a principle, that the electricity used for lighting cannot set fire to anything he is not only in error, but is uttering a fallacy which will lead to the destruction of property, if carried into effect in any electric lighting system.

It is better to meet the issue fairly, and the interests of all will be advanced by the consideration of its dangers, for in no other manner can suitable measures for protection be reached.

In the Mill Mutual Insurance companies there were sixty-one establishments lighted by electricity up to last May.

With few exceptions, the lights had not been in use previous to the autumn of 1881, and many had been started early in the spring.

In these sixty-one establishments I know of twenty-two fires due to electric lighting and assignable to the following causes: eight were from globules of melted copper, or particles of hot carbon falling out from the bottom of the globes. The actual number of fires from this cause was probably many times this number. That class of fires will not continue to happen, as all makers now set their lamp globes in a tight stand with a ridge around the edge. A flat plate will not answer the purpose, as there was one instance where drops of melted copper rolled off and set a fire.

Four fires were due to leaking water or washing floors, and two more were caused by water in a dye-house condensing on the building to which uninsulated wires were fastened. In most of these instances a grounded circuit formed one of the two connections necessary to divert the electricity from the wires. Many of the lower carbons fell from lamps, and five fires were caused where they fell upon combustible material. Three fires were caused by cross arcs from one wire

to another, where uninsulated wires were fastened against conductors. In one instance the conductor was formed by dust settling upon uninsulated wires, and on a damp day it absorbed enough moisture to form a path for the formation of a cross arc, which started a slight fire.

In another instance, the wires were fastened to a damp beam, which was decayed, and was burned nearly in two by the smouldering fire. And in the third instance, damp brickwork in a tunnel was a sufficient conductor to establish an arc which did not do any material damage there, but injured the dynamo. Other fires produced by cross arcs started by water, forming a connection between two wires, have been referred to.

In my connection with electric lighting matters for the Underwriters' Union I know of two fires caused by improper switches; two by water reaching the wires of a circuit already grounded, and one from wires coming in contact with a building, so that their insulation was worn away.

I believe that all these fires should be classed as avoidable fires, because the use of well-known precautions would have anticipated their possibility.

The precautions are known only as a matter of experience, because there was no source of information stating the results from electric lighting currents under certain circumstances.

The damage from these fires was in each instance small, as would be expected. It is the experience of the Boston Manufacturers' Mutual Fire Insurance Company that in mills three-fourths of the fires are in the daytime, and three-fourths of the losses are in the night; so the chance of loss in the night is nine times as great as in the day. During the last two years the introduction of automatic sprinklers has reduced the damage from night fires one-half.

As the electric lights are used during working hours, these accidents come under the head of day fires. When they have happened, there has always been a sufficient number of employés engaged on the premises to attend to the matter at once. When electricity is diverted from the system, the lights are correspondingly diminished, and general attention directed to the difficulty.

Eyre M. Shaw, Captain of the Metropolitan Fire Brigade of London, when in Boston, during his recent visit to America, stated to me that since the introduction of the electric light there had been about one hundred fires in London from this cause.

Electricity forms the safest method of illumination when the following precautions are observed: The system insulated throughout, so that there is no electrical communication with the earth or from one part of the apparatus to another, except through the proper conductors, even if the wires should be exposed to water. All switches made with a lapping connection, so that no arc can be formed. Arc lamps provided with globes closed underneath, and the frame so arranged that the lower carbon could not fall out, even if the clamp failed to hold it securely.

The wires of incandescent systems provided with a sufficient number of fusible links to secure the system against any damage from an excess of current.

The carrying out of these principles in every detail requires careful work and constant watchfulness.

Other features in an electric lighting system are advisable to assure the most satisfactory operation of the apparatus, but they are not essential to secure safety against fire.

The insulation of a system can be assured only by frequent tests. The best instrument for ordinary use is a magneto, which generates an alternating current and rings a bell, like the ordinary telephone "calls." It is used by connecting one wire to the ground and the other to the system. The presence of a fault is indicated by the ringing of the bell when the magneto is put in operation. Means for the systematic trial of the insulation is relatively as important as the use of gauge-cocks on boilers.

If an electric lighting system is sufficiently insulated when first arranged there is no assurance that it will remain so, on account of the numerous changes, blunders, and accidents to which it is subjected, Unfortunately we are not forewarned of any lurking disarrangement of electric apparatus by means of any of the senses, in the same manner that leaking gas appeals to the sense of smell, or as leaking steam produces sound and vapor.

When electric lights become dim in rainy weather it is conclusive evidence of ground connections, which divert the electricity from the system, causing both commercial loss of electricity and great danger of fire. Two contacts are necessary to divert electricity from an electric lighting system. If one contact already exists and connects it with the earth, only one more contact is necessary to conduct a portion of the electricity from the system.

In such an event, if the electricity meets with a conductor of sufficiently high resistance, the electricity is converted into heat sufficient to burn any combustible substance which is present.

Underwriters have two methods of defence against a special hazard: the one to advance the rate to an amount deemed commensurate with the increased danger, and the other method consists in the removal of the source of danger.

With electric lighting the hazard is not an inseparable part of the system, can be obviated by the measures which have been referred to, which are applicable to all systems of electric lighting.

In preparing the Regulations for the Fire Underwriters' Union* I did not ask for any precaution not found by the experience of accidents and actual fires to be essential to protect either person or property.

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*Regulations of the Boston Fire Underwriters' Union for the Use of Electric Lighting Apparatus.—Wires.—Conducting wires over buildings must be seven feet above roofs, and also high enough to avoid ladders of the Fire Department.

Whenever the electric light wires are in proximity to other wires dead guard wires must be placed so as to prevent any possibility of contact, in case of accident to the wires or their supports. Conducting wires must be secured to insulated fastenings, and covered with an insulation which is water-proof on the outside and not easily worn by abrasion. Whenever wires pass through walls, roofs, floors, or partitions, or there is liability to abrasion, or exposure to rats and mice, the insulation must be protected with lead, rubber, stoneware, or some other satisfactory material. Wires entering buildings must be wrapped so that water cannot enter through the tubes.

For inside use, loops of wire must be avoided, and the insulating fastenings arranged to keep the wires free from contact with the building.

Joints in wires to be securely made and wrapped. Soldered joints are desirable, but not essential. Wires conducting electricity for arc lights must not approach each other nearer than one foot, and for incandescent lamps the main wires must not be less than two and a half inches apart.

Care must be taken that the wires are not placed one above another in such a manner that water could make a cross connection.

A cut-out which can be operated by the firemen or police must be placed in the circuit in a well protected and accessible place.

Lamps.—For arc lamps, the frames and other exposed parts of the lamps must be insulated from the circuit. Each lamp must be provided with a separate hand switch, and also with an automatic switch which will close the circuit and put out the light whenever the carbons do not approach each other, or the resistance of the lamp becomes excessive from any cause. The lamps must be provided with some arrangement or device to prevent the lower carbons from falling out, in case the clamp should not hold them securely.

For inside use the light must be surrounded by a globe, which must rest in a tight

The effects of an electric lighting current upon the person bears no relation to the injury which that current can do to property. Electricity has the two properties of quantity and tension, which are independent of each other; the heating effects are due to the quantity, and the results upon the person are proportional to the tension of the electricity.

However, the greater the tension, the more liable is the electricity to force its way through bad conductors. The arc light is produced by a current of high tension and small quantity; the incandescent light is formed by a current of low tension and great quantity.

Therefore, in the arc light system, the most secure insulation is essential; but with incandescent lights, if the insulation were ineffective, there would be more liability of fire. In incandescent lighting systems the whole reliance for safety is not placed upon the insulation, but small fusible links are placed at various points in the wires; so that, if the quantity of the current exceeds a certain amount, the fusi-

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stand, so that no particles of melted copper or heated carbon can escape; and when near combustible material this globe must be protected by a wire netting. Broken or cracked globes must be replaced immediately. Unless a very high globe is used, which closes in as far as possible at the top, it must be covered by some protector reaching to a safe distance above the light.

For incandescent lamps, the conducting wires leading to each building and to each important branch circuit must be provided with an automatic switch or cut-off, or its equivalent, capable of protecting the system from any injury due to an excessive current of electricity.

The small wires leading to each lamp from the main wires must be very thoroughly insulated, and if separated or broken, no attempt made join them while the current is in the main wires.

Dynamo Machines.—Dynamo machines must be located in dry places, not exposed to flyings or easily combustible material, and insulated upon wood foundations. They must be provided with devices capable of controlling any changes in the quantity of the current; and, if these governors are not automatic, a competent person must be in attendance near the machine whenever it is in operation.

Each machine must be used with complete wire circuit; and connections of wires with pipes, or the use of ground circuits in any other method, is absolutely prohibited.

The whole system must be kept insulated, and tested every day for ground connections at ample time before lighting to remedy faults of insulation, if they are discovered.

Preference is given for switches constructed with a lapping connection, so that no electric arc can be formed at the switch when it is changed; otherwise the stands of switches, where powerful currents are used, must be made of stoneware, glass, slate, or some incombustible substance which will withstand the heat of the arc when the switch is changed.

ble link will be melted, and cut off the electricity before other damage could ensue.

Although these safety-catches were originally devised for the purpose of protecting the carbon filaments of incandescent lamps from destruction by extra currents; yet they are essential to assure safety against fire, and it is the use of these safety-catches, and not from the fact that the electrical portions of the system can be handled with impunity, that has given the insurance interests somewhat of a bias in favor of incandescent lighting.

Electric lighting should be encouraged on account of its inherent qualities of safety. Any system that is in conformity to the insurance regulations is also in its best condition electrically.

Electricity, like all forms of energy, is dangerous to the extent that it is not held in control. The same is true of steam in boilers, or water in mill ponds. Like fire, they are all "good servants but poor masters."

Electric Resistance of a Vacuum.—Edlund after repeating and discussing the various experiments upon the non-conductibility of a vacuum finds no evidence that the obstacle to the passage of electricity exists anywhere except in the electrode. He calls especial attention to the resistance which Hittorff pointed out, at the negative electrode, and which De la Rue and Sarasin also observed in their researches relative to the action of magnetism upon the electric discharge in rarefied gases. The proper resistance of the gas diminishes constantly with the pressure of the gas until that pressure has descended to a small fraction of a millimetre. At the same time the resistance to the passage of the current from the gas to the solid electrode continually increases. No good reason has ever been assigned for supposing that these tendencies change their character. It is, therefore, most philosophical to conclude that a vacuum is a good conductor of electricity. Perhaps it would be better to say that electric currents can be propagated with so great facility in a vacuum that the notion of conductibility is deprived of all physical meaning; different material bodies simply produce a resistance more or less great to the propagation of electricity. Their effect in this respect is not active, but pasive.—*Mém. de l'Acad. de Suède.* C.

BRICKS AND BRICKMAKING MACHINERY.

By Cyrus Chambers, Jr.

[A paper read at a stated meeting of the Franklin Institute, December 20, 1882.]

Brickmaking is much more of an art than is usually supposed, and one that has perhaps made less progress than any other.

Bricks are made to-day in many localities much after the manner in vogue among the Egyptians.

True, the increased hardships enforced by their task-masters induced them to try making bricks "*without straw*," and had it not been for this circumstance we might have been making bricks with chopped straw to this day.

Bricks are indicative of the character of nations. Show me the brick of a people, and I will tell you much of their habits, manner of living, their climate, the burthens of their government, and the shrewdness with which they build.

The honest "Friends" of Philadelphia make their bricks to appear just what they are. Their size is convenient for handling, and the building of walls the full thickness specified, and they are proportioned without a desire to make each brick count in height of wall only.

Their "front" or "face-bricks" are not an inferior article painted over, in imitation of something better, but the genuine article, of a beautiful cherry color, and a surface texture of velvety softness that does not reflect the glare of the sun to a painful degree, as do the enameled and other completely vitrified surfaced bricks. The latter may be profitably used externally for ornamental purposes and internally where cleanliness, durability, or ornament make them desirable.

"Philadelphia press brick" are unapproached in richness of color, softness of texture, uniformity of shape, and durability. I use the term "Philadelphia press brick" to designate those made from the best of clay, impregnated with iron, extending from Virginia through Maryland, Delaware and Pennsylvania into the western portion of New Jersey.

It is said in some parts of the United States that a brick seven and one-half inches long and three and one-eighth inches wide will make just as good a "nine inch wall" as the Philadelphia size of eight and one-half by four inches, but I notice that there is no diminution in the

thickness of the bricks, the way they measure in height of wall. They often measure from one-half to five-eighths of an inch in thickness more than ours. Usually the shrewder a people, the smaller and proportionately thicker are their bricks, while the less cultivated use those of larger dimensions, as to length and breadth, but much thinner.

In parts of South America the bricks are from ten to twelve inches wide and eighteen to twenty inches in length, and sometimes only two inches thick. Cuban bricks are a mean between these extremes.

Where there is an "excise duty" upon bricks it exercises a great influence on their size. Then a thousand brick that will build the most wall will command the market.

The manufacture of brick by machinery has been a trying problem to the mechanical engineer.

Brick clays, usually composed of but a small percentage of alumina and a very large proportion of sand, gravel and stones, etc., are antagonistic to machinery, hence the short life of most brick machines.

Although bricks are a common looking commodity, they must possess certain qualities, such as ability to withstand the weather and the hardships of transportation; they must be of the required strength, must cut under the trowel, allow the mortar to adhere, absorb moisture to a certain degree, and withall be cheap. A "front brick," in addition to the above, must be of good surface texture, uniform in size, shape and of a pleasing and uniform color. To produce, by machinery, from rough, indifferent materials, a manufactured article possessing the above qualities is no easy task.

I have labored faithfully twenty years to accomplish this, and with what degree of success I leave you to judge.

During the past season there has been manufactured by our machinery alone, in and near Philadelphia, about *fifty millions* of bricks, at a cost so far below that of making by hand that I hesitate to state it, lest you would think me wavering from the truth. I have before you a *working machine* of one-fourth size, which we will put in operation, and I assure you that I can, with much less care, and greater ease, produce from eighty to one hundred *full sized* bricks per minute, from crude clay, direct from the bank, stones and all, than I can these little ones. This machine has not been dreamed out, or stumbled upon by accident, but is the result of twenty years of study, close observation, and many costly experiments; its parts are all simple, and admirably adapted for working in rough material. The parts that are

subject to great wear by the clay are made of hard iron or steel, fitting together without finish, and may be renewed at trifling cost, thus enabling the brickmaker to always keep the bricks of uniform size and shape, and to produce brick of as good quality at the end of ten years as when the machine was new. This machine is without "moulds" (in the ordinary acceptance of the term), has no reciprocating plungers to grind out, no cams or toggles to wear, but its principal movements are continuous and rotary, and move with an ease and rapidity unprecedented in the history of brickmaking machinery. The general plan of the machine for clays of ordinary qualities is:

1st. A tempering or *pugging device*, by which the clay is ground with water into a stiff plastic mass.

2d. An expressing device, by which the tempered clay is forced out with great force—say with a pressure of fifty tons, on the end of the brick.

3d. A forming device, by which the issuing clay is made to take the desired size and shape of a brick in cross section, but continuous in length.

4th. A sanding device, by which the surface of the issuing bar is coated with fine sand, to improve the surface texture and color, and prevent them from sticking together in the subsequent operations.

5th. A cutting-off device, by which the issuing bar is severed into uniform brick lengths with smooth ends and sharp corners.

6th. An off-bearing apparatus, by which the daily product of one hundred tons of soft manufactured material may be carried five hundred feet, if desired, ready for the further process of drying and burning.

The details of these various operations can best be understood from the diagrams on the screen, and an inspection of the operation of the machine.

Fig. 1 is a prospective view of our brick machine as erected for working ordinary clays, without the use of the stone extractors or clay elevators and mixers.

You see how the clay is fed to the machine direct from the cart and the water put in with it.

Here it is mixed and tempered, then expressed by the gimlet-pointed screw. The round column of clay is brought up square with an excess of clay forced into the corners; the bar then passes through a chamber, containing sand, and finally the spiral steel blade severs

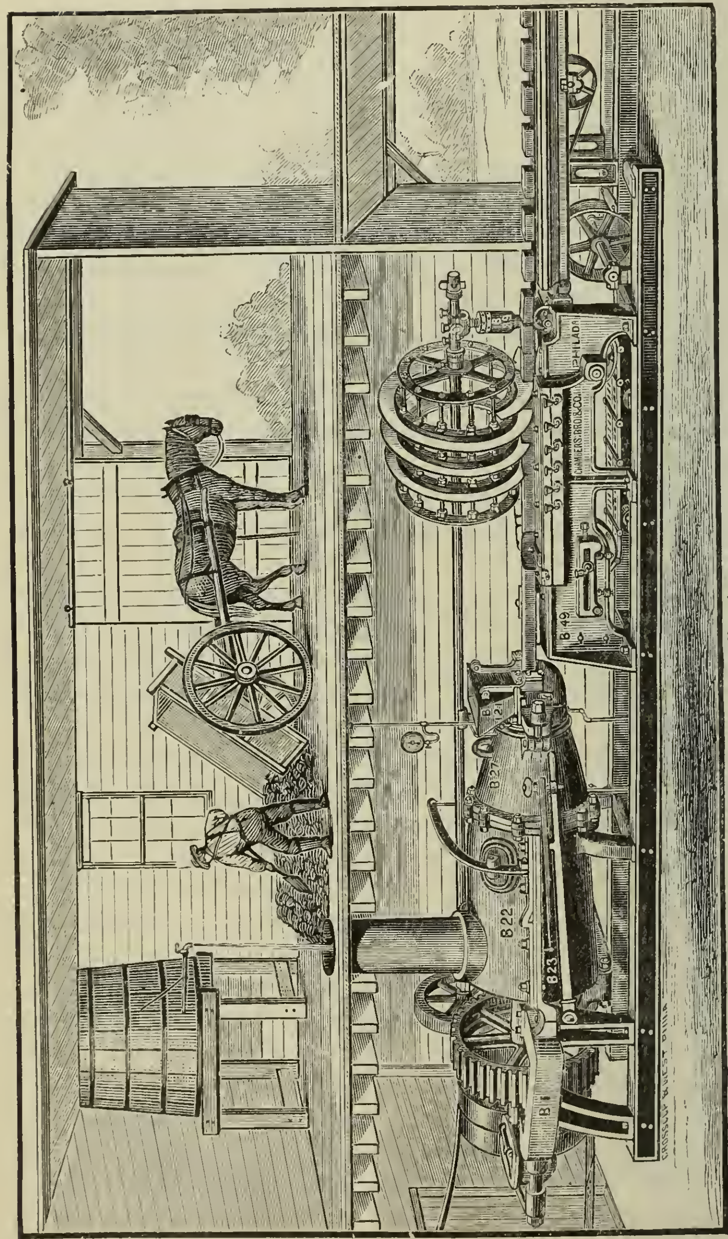

Fig. 1.

the bar into bricks with a long drawing cut, rubbing out its chip and smoothing the end of the brick.

The bricks are then off-borne to the yard to be loaded on drying cars or placed in the hacks for drying. No sun drying is necessary.

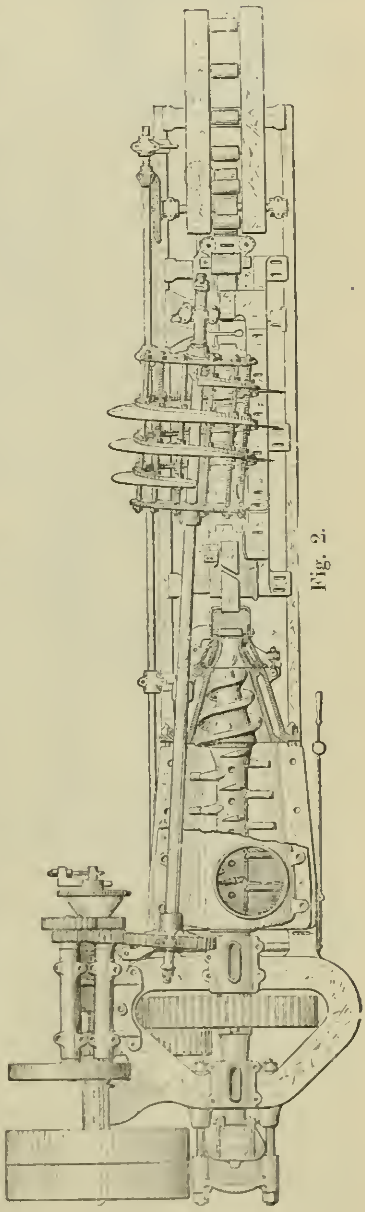

Fig. 2.

Fig. 2 is a horizontal sectional view of the machine, showing the tempering device, and the conical expressing screw. This screw runs in its steam-jacketed and fluted case, which prevents the clay from revolving with the screw, but facilitates its sliding forward, whereby it is "unscrewed" from off the end of the screw, and is forced into the forming die, when it takes shape and issues a "brick-bar."

Fig. 3 represents the *forming-die* held within the steam-heated former case. Plastic materials, moving under pressure, follow the laws of fluids.

The great difficulty heretofore experienced in machines expressing plastic materials has been to make the flowing mass move with uniform velocity through all its parts. As the channel of a river flows faster than the shallow portions, or those near the banks, so does clay move through a die, the friction of the corners holding them back, while the center moves more freely. I overcome this difficulty by the peculiar form of the "former," which you see is so shaped as to facilitate the flow of the clay to the corners, and retard it opposite to the straight

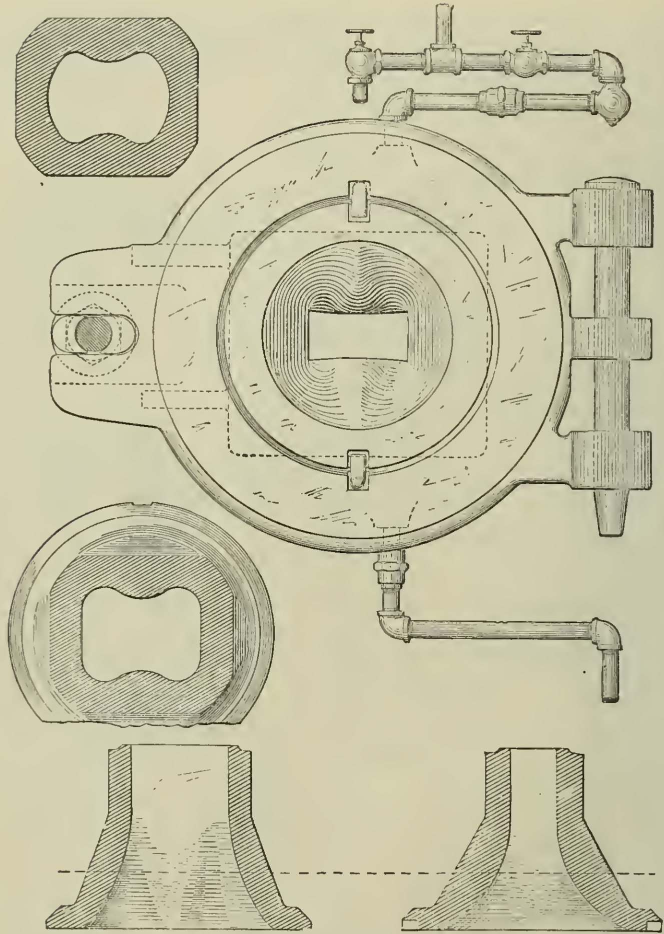

Fig. 3.

sides of the die, the projections being much larger opposite the larger diameter of the die.

For very wide and thin bricks we should omit the resisting projection wholly at the short diameter of the die, or at the edge of the bricks, but facilitate the spreading of the clay outward to the edge, rather than into the corners only.

Fig. 4 (shown on the screen) is the *sanding device*, the original of which was invented by our foreman, Wm. Mendham, and possesses the key to a valuable improvement in the art of making bricks by machinery. It has since been improved by Sanford W. Lasor and

myself, and is the subject of two patents issued and two pending. It performs the function of sanding a brick after it has been moulded, a thing never before successfully accomplished by machinery.

Fig. 5 (shown on the screen) shows side elevation of the machine arranged with the *stone extracting* rolls, clay elevator, and clay mixer and sprinkler, in combination with the brickmaking machine.

There are some clays so tenacious, that it is with great labor that they are got into shape to handle with a shovel, or to soak with water, and at the same time containing boulders of "flint," "granite," or "limestone," the latter of which is fatal to good bricks, if allowed to go into them, even if crushed to powder. At least twenty-five per cent. of the bricks made from "Chicago clay" *burst* by the slacking of the lime, burned from the limestone moulded in the brick.

The conical rolls crush the lumps of clay and reject the stones—ejecting them at the end through a spout.

Sometimes it is necessary to *reduce* the strength of the clay by introducing and mixing with it large quantities of sand and loam, or to mix different quantities of clay.

This mixing device consists of an annular pit, say ten feet in diameter, into which the different materials are dumped direct from the bank, or as in this case, elevated from the stone extracting rolls. Water is supplied from the perforated pipe, carried around and over the clay. As the clay is being sprinkled these curved mixing arms hook under the heaps of different materials, tumbling them over and over, mixing them together and gradually move the mixed and moistened mass into the hopper of the brick machine proper. This device saves the labor of one or two men, besides doing the work much better.

Fig. 6 (shown on the screen) shows a plan view of this device from which its operation can be more readily understood.

Fig. 7 (shown on the screen) shows what we term a set of compound rollers. These are for working very tenacious clays in large lumps. Rolls of small diameter will not take large lumps of hard, tenacious clays, particularly if they be wet on the surface, when they become very slippery. These large rolls run, say two inches apart, griping and crushing the clay to that thickness and rejecting the larger stones. The crushed lumps fall into the smaller conical rolls, where the clay is reduced to sheets or lumps, say half an inch in diameter, and the stones ejected through the spout, the clay falling into the brick machine through the conical hopper. The rollers are made of hard or chilled

iron in the form of shells, whereby they can be easily and cheaply renewed.

Some clays are so sticky, *like tar*, that they defile everything they touch. Such clays cannot be worked in the machines already described, from the fact that they stick with such tenacity to the cut-off blade that it tears the ends of the bricks, and clogs up the cut-off device. Such clays are usually very smooth and free from stones, gravel, or other foreign substances, and may be successfully manipulated by machinery that would be wholly impracticable in ordinary rough clays.

Fig. 8 (shown on the screen) shows what we term our "C" machine. It is composed of the "B" tempering, expressing, and sanding device, with the automatic wire cut-off. This is an entirely new device only very recently reduced to practice, and one that bids fair to fill a long-felt want. The device is clearly shown by the diagram. The device is wholly automatic, and runs without any special care or attention.

Fig. 9 (shown on the screen) shows an embodiment of the leading principles of the already described machines B and C, and is what we term our D or Village machine.

The "motive power" and "the engineer" are to be found on every farm, and the machine is *small, simple,* and *strong,* easily managed, and is designed to produce from eight to ten thousand bricks per day.

There are no elements in it not already shown, but a combination of those best suited for a small, inexpensive brick plant, and is designed to fill a great want, made manifest to us by the number of inquiries we have had for just such machinery.

The machines described as B or C will perform the work of one hundred men without machinery—making ordinary bricks.

The leading features of this machine are applicable to many other uses.

For instance, there is one machine running in this city, producing thirty thousand round cheese per day from cow's milk.

By compressing argilacious iron ores it is working a revolution in *smelting iron,* increasing the yield of the furnace at least ten per cent., improving the quality of the iron, and rendering *ores,* heretofore thrown away as useless, the most valuable.

Our machine is now successfully compressing fine ores from the great Cornwall mines at Lebanon, Pa.

There are on the platform a few thousand minature bricks, made by

the machine now before you, which are at your disposal. Also, some specimens of rough bricks, full size; compressed iron ore, roasted and some unroasted; and as a curiosity, some specimens of "Terra Cotta lumber," not made by our machine, but which can be. We will undertake to produce *joist, scantling, cornice*, or *square saw logs* at the rate of thirty thousand feet per ten hours.

EXPERIENTIAL PRINCIPLES OF CONTROLLED COMBUSTION.

By E. J. Mallett, Jr.

[A paper read at the Stated Meeting of the Franklin Institute, held Oct. 18, 1882.]

I shall confine the remarks which you have kindly invited me to make to a consideration of the industrial consumption of fuel when used in steam generators, and will endeavor to present a new aspect of the subject.

The chemical statics of combustion, that is, the laws governing the cause of the formation of certain resulting gases, which are the products of combustion, are too well known to be adverted to. The chemical dynamics of combustion and inflammation, that is, the intermediate causes brought into action before the final products of combustion escape, are less clearly understood.

Even at present no uniform opinion exists as to why ordinary illuminating gas, issuing from a Bunsen burner, should lose luminosity by the admixture of air with the flame. The general belief is that air, gaining access to all parts of the flame, oxidizes the carbon of the gas, thus destroying luminosity by the instantaneous combustion of the carbon.

The fact, however, that if nitrogen, carbonic acid, or other inert gas, instead of air, enters the openings of a Bunsen burner, the flame will become non-luminous, indicates that it is not oxidation that destroys luminosity.

For our purpose it is useless to advert to the present state of knowledge relative to the chemical dynamics of combustion; the vastness of the subject would tire us. I have endeavored, after thought and experiment, to arrive at some general conclusions, and to contribute towards the elevation of industrial combustion from art to science.

Possibly I should be permitted with justice to enunciate these results as experiential principles.

If fuel energy could be developed through combustion only, unattended with possible inflammation, the problem of rendering such combustion practically perfect might be readily solved. Carbon, however, when insufficiently oxidized, produces flaming carbonic oxide, and, as hydro-carbon fuel always evolves flaming gases, it is the combustion of these flaming gases that presents graver difficulties than would arise if fuel was solely carbon capable of but one combination with oxygen, namely, carbonic acid. To create a science of industrial combustion of fuel we must be able to predict with certainty what furnace devices shall be employed to reduce fuel waste to its minimum.

In searching to remedy the admitted loss of fuel, as universally burned, my method was,

1st, to review and study each cause of fuel loss;

2d, to formulate and prescribe certain principles or necessary and possible conditions essential to perfect combustion, and

3d, to construct mechanical appliances which should be subservient to the principles considered essential.

I will, therefore, this evening treat our subject in conformity with the three classifications just mentioned, and will first refer to causes of fuel waste.

Coal gas, whether generated in a retort or a furnace, is essentially the same. Again, strictly speaking, it is not inflammable; as, *by itself*, it can neither produce flame nor permit the continuance of flame in other bodies. A lighted taper introduced into a jar of carburetted hydrogen (coal gas), so far from inflaming the gas, is itself instantly extinguished. Effective combustion, for practical purposes, is, in truth, a question more as regards *the air* than the gas. Besides, we have no control over the gas, as to quantity, after having thrown the coal on the furnace, though we can exercise a control over that of the air, in all the essentials to perfect combustion. It is this which has done so much for the perfection of the *lamp*, and may be made equally available for the *furnace*.

With reference to the *mode* of introducing the air, it is not a little remarkable that many overlook, or even dispute, the difference in effect, when it is introduced through *one* or *numerous* orifices.

The body of air, by passing through a single aperture, produces the action of a strong current, and obtains a direction and velocity antag-

onistic to that lateral motion of its particles which is the very element of diffusion. In this case, passing along the flue, the stream of air pursues its own course at the lower level, while the heated products fill the *upper one*. It is here evident, according to the laws of motion, that the two forces, *acting in the same direction*, prevent the two bodies impelled by them (the air and the gas) from amalgamating.

The *appearance or non-appearance of visible smoke* is no test either for or against the admission of air, *as to quantity*. The consequences of regulating and varying the quantity of air admitted, so as to suit the varying state of the furnace, as regards the quantity of gas given off, also deserves attention. It is quite certain that, to effect the perfect combustion of all the combustible gases produced in a furnace, a large demand for air (distinct from the air entering the grate) *always exists;* also that by entirely *excluding air* smoke is produced, and the heat diminished in all states of the fire.

Chimney draught, operating through the levity of hot air, causes a fuel loss, varying with the rate of combustion, and which may amount in practice to 35 per cent. of the total heat produced.

A FIRST fuel loss arises from air entering the furnace, and absorbing a much larger amount of heat than it gives back before it passes out of the chimney.

Of the two combustible constituents of coal, the carbon and the hydrogen, the former is a solid and the latter is a gas. When coal is sufficiently heated the hydrogen escapes and the carbon, for the most part, remains behind. This is what occurs in a retort in the manufacture of illuminating gas.

The same thing occurs to a certain extent when a fresh charge of coal is thrown into a furnace. The cold fuel at first chills the fire, and after the expulsion of its moisture becomes hot enough to decompose and unite with oxygen. A most important fact must here be observed, namely, that the carbon does not burn until after the hydrogen. A fire box of a furnace thus simulates a gas retort, producing volatile hydrogen, which passes up a big gas pipe, the chimney, and is lost in space, unless we contrive to bring enough oxygen in contact with it to burn it before it enters the chimney.

A SECOND fuel loss is caused by unburnt hydrogen and hydrocarbons distilled from the coal passing up the chimney into space.

A THIRD fuel loss arises from furnace suffocation, or too little air.

A deficiency of air simply means a production of carbonic oxide and

loss of heat. It must not be assumed, however, that it is only all-sufficient to admit a full supply of air through the grate of a furnace to produce a perfect combustion of the fuel.

A FOURTH fuel loss is caused by all the necessary air entering only through the ash-pit of a furnace.

Suppose, as is always the case in a firebox, that another stratum of coal or carbon is above the first tier. The carbonic acid produced by the burning of the lower layer, in passing through the superimposed layer, unites with more carbon and becomes converted into carbonic oxide. It is evident, therefore, that when coal is burning in layers the property possessed by carbon of uniting with carbonic acid produces the same effect, in a less degree, however, as if too little air was being supplied.

If, however, this escaping carbonic oxide could meet an additional supply of oxygen above the fuel it would be burned and pass off as carbonic acid.

Although carbonic oxide will burn when mixed with air and produce heat, this can only occur at a certain temperature; if, therefore, cold air comes in contact with carbonic oxide, escaping above the fuel, it will mix with it without inflaming it, consequently,

A FIFTH fuel loss arises from the admittance of air above the fuel at a temperature below the burning point of the escaping carbonic oxide.

The supply of air to fuel must be divided into two volumes, one to maintain the combustion of the solid fuel and the other to burn not only the carbonic oxide passing off the surface of incandescent fuel, but also to ignite the gases produced from the hydrogen of the fuel.

As a fresh charge of coal cools a fire, and as cold air entering beneath a grate is also a cooling agency, it is evident that at the moment a fresh charge of coal enters a furnace the proportion of air entering beneath and above the grate should be changed. More air should enter above the fuel to burn the rapidly forming gases, and less should enter through the grate, because less is required, and a diminished supply will prevent the cooling of the fire.

A SIXTH fuel loss, therefore, arises from unvarying volumes of air entering beneath and above the fuel.

As the volume of air entering a furnace in a given time depends upon the velocity with which it travels it is evident that

A SEVENTH fuel loss is caused by the existing adequate means of

regulating the amount of air entering a furnace, owing to its variable velocity.

It is therefore necessary to know the rate of a current of air when entering a furnace before we can decide on the necessary area for its admission. As the furnaces in use operate with open ash-pit, an attempt is made to make the grate-bars answer for dampers. That is, so many square inches of area of aperture between the grate-bars is allowed for so many square feet of grate surface.

If, for example, six square inches of opening is allowed for each square foot of grate surface, with air moving at six feet a second, the same amount of air moving at forty feet a second would enter one square inch of opening. Therefore, without knowing the velocity of the air, no regulation of air can be made by the grate openings. In practice, the importance of knowing how much air enters between grates is entirely ignored.

The velocity of air entering a furnace by chimney draft varies with the heat of the fire, therefore when a fresh and cold charge of fuel is thrown into a furnace the draft diminishes at the exact time when more air is required to burn gases and prevent smoke.

An EIGHTH fuel loss arises from the admission of air to furnaces in bulky instead of divided currents.

It is obvious that air entering the ash-pit becomes thoroughly subdivided in passing upwards through the grates, but this does not obtain with air introduced above the fuel, unless special provision is made.

The necessity of having hot air in fine currents to complete the combustion of fuel gases indicates the serious objection of permitting air to enter through the furnace door opening, or even through the door itself. If we carefully consider that for the combustion of fuel gases the desideratum is to have the necessary oxygen at the right place at the right moment, it is evident that any air entering beneath the bars or through the door is necessarily a little in arrear of the gases to be burned in the combustion chamber of a furnace.

Although the entering air may move with the same velocity as the unconsumed gases, it *connot catch up with them*, because the start is uneven.

A NINTH fuel loss consequently arises from the admission of air for the combustion of fuel gases at any point except just where it was wanted at the moment, namely, in the hottest part of the combustion chamber.

A TENTH cause of fuel loss is the cooling effect of heat-absorbing surfaces in proximity to the burning fuel, and the sequel to this is

An ELEVENTH cause of fuel loss, arising from lack of capacity of the combustion chamber to burn fuel gases before they are forced through a steam boiler.

The dilution of oxygen by nitrogen in our air is very nicely suited to industrial combustion ; if, by further dilution, the amount of oxygen in a cubic foot of air becomes decreased, the rate of combustion diminishes. After a certain dilution, combustion cannot be maintained at all. It follows, therefore, that every additional volume of steam or other non-supporter of combustion which gains access to the combustion chamber of a furnace interferes with combustion. Therefore

A TWELFTH fuel loss arises from steam, in addition to the air necessary for combustion, gaining access to the combustion chamber of furnaces.

A THIRTEENTH fuel loss arises from the escape of carbonic oxide and smoke.

When smoke is once produced in a furnace it is as impossible to burn it or convert it to heating purposes as it would be to convert the smoke issuing from the flame of a candle to the purposes of steam and light.

The presence of smoke being noticeable no test other than the eye is required. Carbonic oxide, however, is invisible and inodorous, and must be sought for by other means.

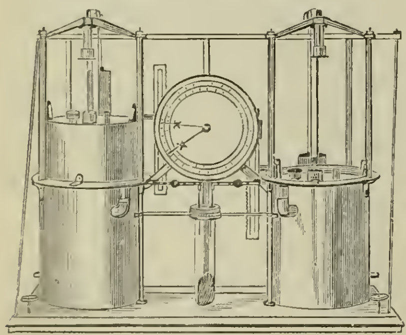

Fig. 1.

Again, the presence of free oxygen in the gases of combustion indicates that more air than necessary is being supplied to the furnace. In order to readily detect the presence or absence of these gases in furnace products I constructed an apparatus called a differential furnace gas meter which records on a dial the per cent. in volume of any gas existing in escaping flue products.

Fig. 1 represents two gas-holder tanks, in which two cylinders of equal capacity are counterpoised. Geared to each cylinder is a separate index-needle, which is caused to revolve around the dial by the

upward or downward motion of the cylinder. Between the cylinders is a glass receptacle in which any gas-absorbing material can be placed. When it is desired to test furnace gases a small pipe introduced into the furnace flue permits the gases of combustion to enter one of the cylinders by aspiration, when the cylinder is caused to ascend. Now, while the cylinder is at its greatest height, the corresponding cylinder rests within the tank entirely filled with water. If, now, the first cylinder is caused to descend by being weighted and the induction pipe is closed, while the pipe leading to the intermediate glass vessel is opened—the gases contained in the first cylinder being expelled, pass through the absorber into the second cylinder, which in turn begins to rise.

As both cylinders are of exactly the same capacity, the one descends proportionately as the other ascends. If, however, any of the gases passing through the absorber are taken up, it is evident that the ascending cylinder will not rise as rapidly as the first cylinder descends. As each index needle is geared independently to each cylinder, any difference of motion in the cylinders is registered on the dial; and the divergence between the two needles, when the descending cylinder has reached the bottom of the tank, indicates the per cent. of gas which has been absorbed, and, consequently, the amount present in the gases is thus analyzed. This apparatus diminishes the risk of error to the minimum, owing to the large capacity of the cylinders, each holding eight hundred cubic inches. The apparatus was invented for the purpose of verifying the results which were anticipated would be produced by the system of "Controlled Combustion."

The "Experiential Principles," which may be reduced to twelve, naturally do not embrace all the necessary conditions of combustion.

I. Hydrocarbon fuel tends to burn with less carbonic oxide and smoke, proportionately as its environing atmosphere diminishes in tension.

II. Hydrocarbon fuel tends to evolve carbonic oxide and smoke, if burned in a furnace, until the temperature of the fuel reaches a certain elevation.

III. The tension of fuel gases within a furnace is never less than that produced by the burning of the fuel itself by natural draft, and is never sufficiently low, when compared with the rate of combustion, to prevent the origination of smoke.

IV. What was considered probable by Rankine, Peclet and others

is demonstrated in "Controlled Combustion," namely, that air for dilution in furnace combustion would be rendered unnecessary, providing chimney draft could be dispensed with, and providing also that without such draft a supply of sufficiently heated air, in divided currents, could enter the combustion chamber in regulable quantities.

V. To maintain an atmosphere of the desired tension within a fire-box, an air exhauster must supplant the chimney, and the influx of air into the ash pit must be throttled.

VI. When combustion is urged by a blast fan, causing furnace air tension to be greater than normal barometric pressure, both physical and chemical actions result, differing from those created by a draft or flue fan, incompatible with perfect combustion.

VII. Hydrocarbon fuel, freshly charged into a furnace, must not be supplied with air to initiate its burning until the temperature of the fuel is sufficiently elevated; *i. e.*, the fuel must begin to distil before it begins to burn.

VIII. To compel a rapid and intimate mixture of hot air with combustible fuel gases, generated within a boiler fire box, these gases must not be allowed to ascend or envelope the boiler until after they enter the combustion chamber through channels in close proximity to those conducting fresh heated air into the combustion chamber.

IX. The heat from escaping furnace gases, after leaving a steam boiler, is more completely radiated for additional heating and boiling of water, if such gases are rendered athermous by being kept at their dew point.

X. It is possible, in practice, to superheat all the feed water required by a steam generator, from the waste heat of escaping gases, to a temperature equal to that of the water within the generator, and also to supply a portion of the feed in the form of steam.

XI. The potential power of a steam generator may be increased to a hitherto greater limit without diminishing the economic result

XII. To burn fuel rapidly, without creating a too high localized temperature, it should not be supplied with sufficient air to burn it at once to carbonic acid only, but considerable carbonic oxide should be produced, to be afterwards burned in the combustion chamber.

The application of these experiential principles in "Controlled Combustion" is effected by the following mechanical devices. With reference to the First Principle, it is known that as air becomes compressed it more nearly approaches the solid condition, and as its

tension is decreased, so in direct proportion is its molecular mobility increased. An alcohol flame, which burns almost invisibly, is rendered quite luminous if burned in an atmosphere much above normal barometric pressure, and by a continual compression of the air the flame becomes smoky. Conversely, a candle flame burns almost invisibly at great altitudes. When by air compression its molecular mobility is increased, it penetrates a flame less rapidly than air of less tension. Smoke and carbonic oxide tend to originate whenever the atmosphere in which a hydrocarbon fuel is burning is not sufficiently mobile to rapidly penetrate flame and oxidize the carbon before it escapes. Part of the equipment required with "Controlled Combustion" consists of a register which can completely close the openings in the door of the ash pit, as represented in Fig. 2. When bituminous coal is first thrown into the furnace the temperature of the fuel must become elevated before the fuel is permitted to burn, as set forth in Principle VII. To this end the lever shown in Fig. 5, and actuating the ash pit opening, is caused to completely close it. Now, as the flue fan (see same Fig.) is at all times exhausting the furnace gases, and as no air can enter the ash pit, the fresh fuel cannot burn, but merely begins to distil as it would in a gas retort. After the temperature of the fuel is sufficiently high its burning is allowed to begin by the admittance of air through the ash pit. As, however, the air gaining access to the fire box through the ash pit is throttled, the atmosphere within the fire box is kept at a lower tension than is possible with chimney draft. By this means the coal burns without originating carbonic oxide and smoke, and the demands of Principles I, II and VII are responded to.

The "Experiential Principles" formulate, as it is believed, absolute conditions demanded for a perfect combustion of fuel and a greater utilization of the heat of escaping gases, and, as practice fully sustains the ideas advanced, force is given to the following statement, namely:

That it is impossible to burn by hydrocarbons, either in a furnace, a lamp or gas burner, without the production of carbonic oxide and smoke, unless more air environs and dilutes them than is theoretically required for their combustion, and that proportionately as the density of the environing atmosphere decreases, within limits, so will the amount of air required to burn fuel without smoke diminish and approach nearer to the amount theoretically required for a perfect combustion. If it were possible by any device to only mix the theoreti-

cal amount of hot air with sufficient rapidity and intimacy with fuel in a furnace, it is obvious that no carbon could escape oxidation; as, however, this is as yet practically unattainable, we must either use a surplus amount of air required theoretically, and thereby produce waste, or endow air with greater molecular mobility by reducing its density, and thus favor its mixing capacity.

With reference to Principle III, it should be appreciated that the tension of furnace gases depends upon the rate at which the fuel is burned.

It therefore follows that the tension is limited and uncontrollable. If we attempt to prevent carbonic oxide and smoke by lessening the air tension, then we must increase the rate of combustion. What is required, however, is to lessen the tension in a greater ratio than is possible by increasing the rate of combustion. It is obvious that natural or chimney draft, *i. e.*, draft produced by the fuel itself, depending as it does upon the rate of combustion, can only be increased at a fixed ratio.

To enforce the requirements of Principles IV and V, chimney draft is entirely dispensed with in "Controlled Combustion," being replaced by mechanical draft. A suction fan, as represented in Fig. 2, is employed, requiring a power to actuate it amounting to about three per cent. of the total fuel power.

Although various methods have been adopted to introduce hot air in subdivided currents into a combustion chamber, experience has shown that such air never really reached a sufficiently high temperature. In the present system tubular grate bars are employed, open at both ends. The boiler front is perforated, as shown in Fig. 2, such perforations being coincident with the front opening of the grate bars. The rear end of the bars passes through an iron box within the bridge wall, or rather septum wall, as shown in the furnace, Fig. 3.

As the air openings to the ash pit can be throttled, the air necessary for the combustion of the fuel gases can be compelled to pass through the tubular grate bars, and thus enter the combustion chamber in divided currents of a high temperature.

As it is necessary to regulate the air entering the ash pit simultaneously with that passing through the grate bars, the lever is made by one motion to actuate the air resisters of the grate bars, and also the ash pit door registers.

With reference to Principle V, it may be stated that although an

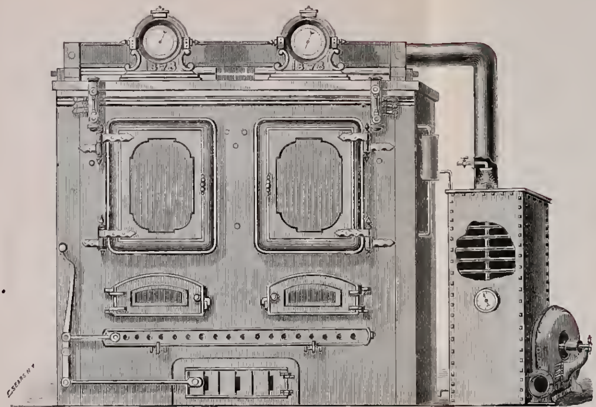

Fig. 2.

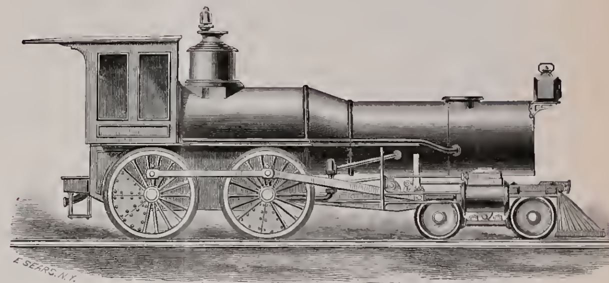

Fig. 4.

Fig. 3.

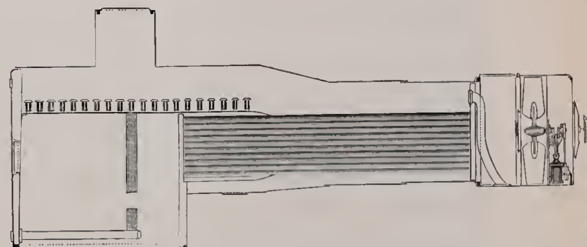

Fig. 5.

air exhauster diminishes the tension of fuel gases in the fire box, still, if the influx of air through the ash pit is not properly regulated, a sufficiently low air tension will not result.

With respect to Principle VI, it should be noted that if air is supplied to a furnace by a blast fan it is obvious that the air pressure within the fire box is greater instead of less than normal barometric pressure. The physical result of forced air is to cause the flame from the fuel to tend to rise at right angles to a grate surface, and to impinge directly upon that part of the boiler situated directly over the fire box. The chemical result of hydrocarbon fuel, burning in an atmosphere of greater or less tension than the normal, has already been adverted to.

There are two causes that produce the liberation of carbon from fuel in an unoxidized condition, *i. e.*, as smoke, namely, a low temperature of the fuel, and an insufficiently low air tension within the fire box. To respond to the demands of Principle VII, a fresh charge of bituminous coal is not allowed to burn when first thrown into the fire box. At this time the lever is caused to close the air openings of the ash pit. The fresh fuel, from the heat derived from the already incandescent fuel, begins to distil, and the chemical actions resulting in a gas retort are simulated. The draft fan, inducing powerful currents of air to enter the combustion chamber through the hollow bars, permits the fuel gases distilled from the fuel to be burned. After a certain lapse of time, depending on the grade of fuel, the ash pit air registers are opened, whereby a real burning of the fuel begins.

Principle VIII indicates that although every possible provision may be made for the admittance of hot air, in divided currents, into the combustion chamber of a furnace, an imperfect admixture of the air results unless special provision is made to prevent the unconsumed gases from rising upwards, and thus get cooled before they come in contact with the air necessary for their combustion.

To this end the furnace in the present system is divided by a septum wall into the fire box proper and the combustion chamber, as shown in the sectional views, Figs. 3 and 4.

As the openings of the septum wall, through which flame and unignited fuel gases pass, are only slightly above the rear openings of the hollow grate bars through which fresh hot air is flowing, a rapid and intimate mixture of gases and air results.

We are indebted to the interesting experiments of Professor Tyn-

dall (see "Heat as a Mode of Motion"), which show how air entirely freed of moisture permits radiant heat to pass through it without absorbing any of such heat; and, conversely, how air saturatud with moisture is a rapid absorbent of radiant heat. Tyndall also shows that in proportion as the radiant heat absorbing power of moist air increases is its power to radiate its own heat increased. It should be remembered, also, that moist air conducts and convects heat with infinitely greater facility than dry air.

Now, as fuel gases obey the same law, it is obvious that in order to compel them to radiate, conduct and convect their heat with the utmost rapidity they should be saturated with moisture and be maintained at their dew point. Air rendered by moisture opaque to radiant heat is in an "athermous" condition. As fuel gases, after having imparted say seventy per cent. of their heat to a steam boiler cannot liberate the balance with equal facility, owing to their reduced temperature, the process of moistening such gases is resorted to in "Controlled Combustion."

In practice, such escaping fuel gases, before they are drawn through the fan to be delivered into space, pass through what is termed an "Athermous Superheater."

This appliance, represented in Fig. 2, consists of an air-tight case, containing iron pipe of any desired amount. The gases, just previous to entering the superheater, are moistened to saturation by the water spray shown in the same figure. The exhaust steam from the engine that actuates the fan, together with the water spray, maintains the air at its dew point, which is evidenced by the constant dropping of water from the pipe seen to project from the side of the superheater near its base.

The effect of this is to cause the escaping gases to be cooled down to a lower temperature than has been hitherto possible. The amount of water supplied by this spray is quite an insignificant quantity.

The superheater effectually fulfills the requirements of Principles X and XI. It is most desirable to heat feed water to as high a temperature as possible, each 100° Fahr. being equivalent to about ten per cent. saving of fuel. The "Athermous Superheater" receives the cold water supply from a pump at the base of the packed tubes. The water here enters a manifold, and distributes itself through the layers of pipe, passing in an upward course. The moistened heated gases enter the superheater at the top, and pass between the piping which

is at right angles to the current of gases, and then enter the exhaust fan.

The upper manifold of the superheater connects with what is termed a "Separator," which consists of a steam-tight cylinder, into which the superheated water separates into steam, which enters the steam space of the boiler, and boiling water, which is forced into the feed water pipe of the boiler. The "Separator" is seen in Fig. 2, placed between the superheater and the boiler. As the superheater is, in fact, an auxiliary steam generator, it is provided with a steam gauge, the pressure of which is always slightly above that of the steam boiler itself. The feed water, before entering the boiler, becomes heated to the same temperature as the water within the boiler, and, as a part of the feed enters the boiler as steam, a great saving of fuel is realized.

The facility with which furnace gases at their dew point are made to part with their heat permits of a rapid rate of combustion without a corresponding loss. It is thus that what is said in Principle XI, relative to the potential power of boilers, becomes realized.

The question of localized temperature is an important one when fuel is being rapidly burned under a steam generator. Principle XII indicates that the fuel should in part be burned in stages. If more than twelve pounds of air to the the pound of fuel enters a furnace, the temperature will be less than with just the theoretical amount; and if less air than is required for the perfect transformation of the fuel into carbonic acid enters the furnace, this will also produce a lower temperature of combustion. What is required, therefore, is to supply fuel with as nearly twelve pounds of air as possible, and to divide the weight of air between the fuel and the fuel gases, so that while, for example, eight pounds of air is supplied through the ash pit, the remaining four pounds will enter the combustion chamber. Thus the fuel does not receive enough air to entirely burn it to carbonic acid, whereby a too intense localized temperature would result, but a supply so gauged as to produce considerable carbonic oxide, to be afterwards consumed by the air entering the combustion chamber. In the present practice under consideration this is what is undertaken. The air registers in the ash pit throttle the supply from that quarter, and the hollow bars admit air into the combustion chamber to make up for the deficiency.

The saving of fuel in "Controlled Combustion" originates from three distinct sources:

1st. A practically perfect combustion.

2d. A utilization of heat from furnace gases hitherto allowed to escape.

3d. A use of cheap fuel, such as anthracite, buckwheat or dust, or bituminous dust, permissible by the increased draft.

The equipment for the system of "Controlled Combustion" can be applied to the existing forms of locomotive, marine, and stationary boilers. Fig. 5 illustrates the exterior of a locomotive. It will be noticed that the smoke funnel is dispensed with. The invisible products of combustion escape through an opening on the periphery of the extended boiler casing, not shown in the engraving. The exhaust nozzles are not used, the draft being produced by the exhaust fan, shown within the boiler casing in Fig. 4. By this plan a powerful draft can be produced, even when the locomotive is at rest, by the small engine which actuates the fan. The engines of the locomotive are relieved from the back pressure caused by exhausting steam through the nozzles, and the resonant noise is avoided. The exhaust steam is delivered through the pipe seen along the side of the locomotive, from whence it passes into the exhausting compartments of of the tender, to be described.

Fig. 4 represents the interior view of the boiler, where the fire box is seen to be separated from the combustion chamber by a fire-brick division or septum, as already alluded to.

The tender is divided into three compartments. The upper one is the receptacle for the fresh water; the middle one contains copper tubes, communicating with the external air in front, and with a suction fan in the rear. The exhaust steam circulates around the upper tubes, and becomes in part condensed, the resulting hot water falling into the lower compartments. The uncondensed steam then comes in contact with a spray of water falling from the upper compartment, and the condensed water also enters the lower compartment, from whence hot water is pumped into the boiler.

The air used to condense the steam is employed for HEATING AND VENTILATING CARS, being delivered through a conduit, which, with coupled ends, passes beneath the cars. Three registers in the floor of the car admit the heated air. This system does away with coal stoves or heaters, and supplies the car with fresh air and warm air.

Figs. 2 and 3 represent the equipment for stationary boilers, already described. The lever is seen to actuate both the ash pit, air registers

and those controlling the air passages through the tubular bars. The Athermous Superheater, seen on the right of the boiler, superheats the feed water, and then, by means of a Separator, seen between the superheater and the boiler, together with some steam, passes into the steam space and water space of the boiler. The exhaust fan can be operated either by a small engine or by one already in operation. A small amount of boiling water taken from the feed pipe is caused to constantly moisten the hot gases which enter the superheater, and thus maintains them at their dew point, so as to facilitate the radiation of their heat to the stacked pipes. The superheater, being in effect an auxiliary steam boiler, is supplied with a steam gauge, the pressure on which is always slightly greater than that of the boiler.

OLSEN'S TESTING MACHINES.

From the Report of the Secretary, November 15, 1882.

Universal Testing Machine.—The illustration (Fig. 1) represents a testing machine of 50,000 pounds capacity, combining certain novel and useful features, introduced for the purpose of subjecting materials used in construction to every variety of strain. The machine was designed and constructed by Mr. Tinius Olsen of Philadelphia, a member of the Institute, for the Renssalaer Polytechnic Institute of Troy, and was made especially with the object of universal service, for scientific investigation and instruction. It is adapted for making tensile, crushing, transverse, and torsional tests.

The strain is applied with screws and gearing, and is operated by a crank shown in front of the cut. It is also provided with quick return motion. To bring this into play the large crank and small pinion is removed, and the larger intermediate gear-wheel turned by a handle on the same.

For convenience, and with the object of enabling the machine to be easily operated by the experimenter without help, an arrangement is added for operating the gears and screws by foot. This arrangement is represented in the illustration by the long lever crossing the lower gear-wheel of the machine.

The strain to which the specimen of material operated upon is subjected will bear upon the platform of the machine, which is supportod on a system of scale levers, and the amount of the strain balanced

and indicated on the beam, in the main similar to the arrangement of a platform scale.

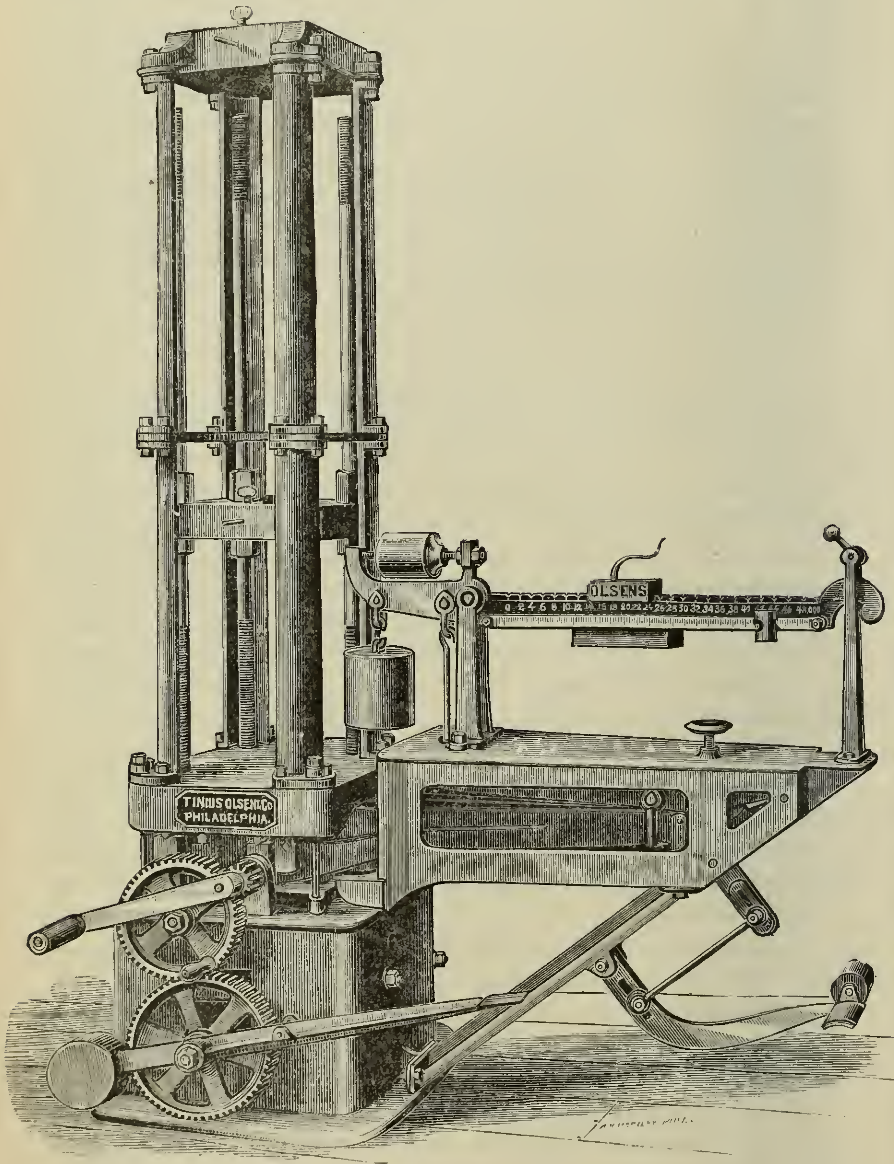

Fig. 1.

As the machine is represented in the cut, it is arranged for testing long specimens in tension up to 5 feet lengths. For ordinary short specimens of 2 feet lengths and less the top part can be removed, thus making it more convenient to place and replace specimens, as a man can then reach both ends of the specimen when standing on the floor alongside the machine.

As a new, and for scientific investigation important feature, this machine is provided with an arrangement for applying intermittent strains, whereby a specimen under a certain strain may be instantly subjected to a certain increased strain and again as suddenly released. When an ordinary test is made the foot lever to the right of the machine is in position when up under the frame of the machine. The intermittent strain is applied by depressing this lever, and the amount of this extra strain is measured on the weighing beam, and set or limited to the desired amount by the screw and hand-wheel, shown under the weigh beam.

With this machine, then, the experimenter is enabled to apply a very gradual and quietly increasing strain, which can be obtained by the use of screws and the crank motion; also, when desired, a sudden and intermittent loading or series of strains of any desired duration.

In the size of machine illustrated (of 50,000 lbs. capacity) the intermittent strains can be regulated to any desired amount up to 30,000 lbs. by the exertions of one man, the maximum amount depending upon the rigidity of the material experimented with. Machines of this kind have been built up to 200,000 pounds capacity.

Horizontal Chain Testing Machine.—Fig. 2 represents a horizontal chain testing machine (built for the Iron City Chain Works, Pittsburgh, Pa.), capable of stretching out and testing 15 fathom length of chain, and consists of a straining device and a recording device, both arranged at the same end of the machine so that all the working parts are under the eye of the operator.

The straining device in this case consists of hydraulic cylinder, power pumps and a device for changing and stopping the motion of the piston in the cylinder without stopping the pumps as well as an automatic stopping arrangement at each end of the stroke of the piston.

The recording device consists of scale levers and a beam with sliding poises.

The hydraulic cylinder presses against the main levers, and this again transfers the strain to the equal beam, which alters the horizontal stress

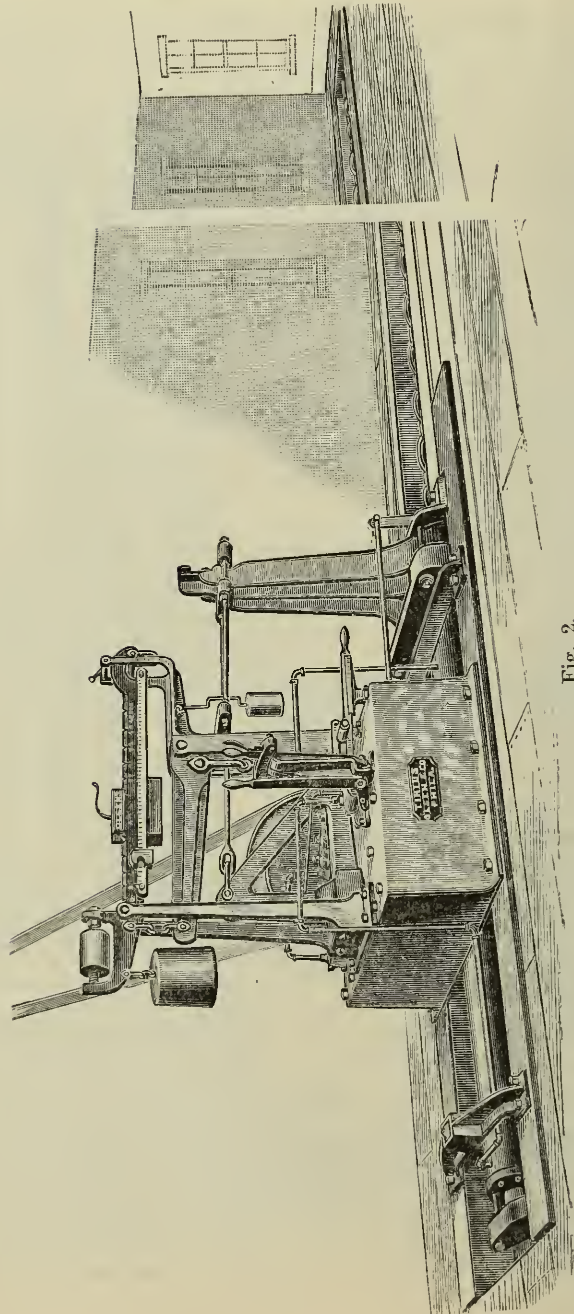

Fig. 2.

to a vertical one, and is further transmitted through the intermittent lever to the beam where it is balanced and recorded.

One of the features secured in this arrangement for horizontal machines is that the machine can be sealed with standard weights and sealing levers the same as is done in sealing a platform scale, or one of the vertical machines.

THE SPECTROSCOPE AND THE WEATHER.

By C. Piazzi Smyth,
Astronomer Royal for Scotland.

What may be done with the spectroscope in the matter of weather is, for the present at least, confined almost entirely to the question of rain—as, Will it rain, or will it not; and, if it will, heavily or lightly? The manner in which the spectroscope acccomplishes this useful part is by its capacity for showing whether there is more or less than the usual quantity of watery vapor permeating the otherwise dry gases in the upper parts of the atmosphere, this watery vapor not being by any means the visible clouds themselves, but the invisible water-gas out of which they have to be formed, and by means of which, when over-abundant, they obtain their privilege for enacting rain-fall. So that never were wiser words uttered and more terse philosophy than those which are to be found in the ancient book of Job, wherein, of the wondrously "balanced clouds" high up in mid-air, it is said, "They pour down the rain according to the vapor thereof."

More or less of this water-vapor is always in the air, even on the very clearest days, and a happy thing for men that it is so; for, as Dr. Tyndall and others have well shown, it moderates the excesses of hot solar radiation by day and cold radiation of the sky at night, and is more abundant in the hotter than in the colder parts of the earth. Wherefore, according largely to its temperature for the time being, the air—otherwise consisting almost entirely of nitrogen and oxygen —can sustain, and does assimilate, as it were, a specified amount of this watery vapor, invisibly to the naked eye, the microscope, or the telescope; but not so to the instrument of recent times, the spectroscope. And if the air vertically above any one place becomes presently charged with more than its usual dose of such transparent watery

vapor (as it easily may, by various modes and processes of nature), the spectroscope shows that fact immediately, even while the sky is still blue; clouds soon after form, or thicken if already formed, and rain presently begins to descend.

But how does the spectroscope show to the eye what is declared to be invisible in all ordinary optical instruments? It is partly by its power of discriminating the differently colored rays of which white light is made up, and partly by the quality impressed on the molecules of water at their primeval creation, but only recently discovered, of stopping out certain of those rays so discriminated and placed in a rainbow-colored order by the prism and slit of the spectroscope, but transmitting others freely. Hence it is, that on looking at the light of the sky through any properly adjusted spectroscope, we see, besides the Newtonian series of colors from red to violet, and besides all the thin, dark Fraunhofer, or solar originated lines, of which it is not my object now to speak, we see, I say, in one very definite part—viz., between the orange and yellow of that row of colors, or "spectrum," as it is called—a dark, hazy band stretching across it. That is the chief band of watery vapor; and to see it very dark, even black, do not look at a dark part of the sky or at black clouds therein, but look, rather, where the sky is brightest, fullest of light to the naked eye, and where you can see through the greatest length of such well-illumined air, at a low, rather than high, angle of altitude, and either in warm weather, or, above all, just before a heavy rain-fall, when there is and must be an extra supply of watery vapor in the atmosphere. Any extreme darkness, therefore, seen in that water-vapor band beyond what is usual for the season of the year and the latitude of the place is an indication of rain-material accumulating abnormally; while on the other hand, any notable deficiency in the darkness of it, other circumstances being the same, gives probability of dry weather, or absence of rain for very want of material to make it; and the band has, therefore, been called, shortly, "the rain-band." Thus, also, "rain-band spectroscopes" have been specially constructed by several most expert opticians in size so small as to be carriable in the waist-coat-pocket, but so powerful and true that a glance of two seconds' duration through one of them suffices to tell an experienced observer the general condition of the whole atmosphere. Especially, too, of the upper parts of it, where any changes—as they take place there almost invariably earlier than below—enable such an observer to favor

his friends around him with a prevision of what they are likely soon to experience.

As an example of what may be done, and done easily, after a certain amount of experience and understanding of the subject has been acquired, I append, from a lady's meteorological journal, her notes of the mean temperature of the air and the intensity of the-rain band for each of the first fifteen days of the present month, and in a final column have entered the amount of rain-fall measured at the Royal Observatory, Edinburgh, on each of those days. The darker the rain-band the larger is the figure set down for it, and it will be seen pretty plainly, on running the eye down that column and the next one, that with an intensity of either 0 or 1 no rain follows, or, we might almost say, can follow; but with an intensity of 2 rain-fall begins, and with 3 it may be very heavy. All these rain-band notes have been made with a spectroscope no larger than one's little finger, purchased some six years ago, and taken on many voyages and travels since then:

Date, September, 1882.	Mean temperature of the air.	Rain-band intensity.	Depth of rain measured in gauge at Royal Observatory, Edinburgh.
	Deg. Fahr.		Inch.
Friday, 1,	57·1	3	·044
Saturday, 2,	59·2	2	·353
Sunday, 3,	58·6	2	·015
Monday, 4,	54·4	0	0
Tuesday, 5,	55·7	1	0
Wednesday, 6,	55·2	0	0
Thursday, 7,	53·8	1	0
Friday, 8,	59·4	0	0
Saturday, 9,	54·0	1	0
Sunday, 10,	57·0	1	0
Monday, 11,	52·2	1	·040
Tuesday, 12,	48·6	0	0
Wednesday, 13,	52·8	1	0
Thursday, 14,	49·5	3	·62
Friday, 15,	56·2	2	·570

But, if so much can be done by so small a spectroscope, the question may be well asked whether more still might not be accomplished with a bigger and more powerful one, especially seeing that the dispersive powers of both chemical and astronomical spectroscopes have in late years been increased to a most astonishing extent. The ques-

tion is important, and somewhat new as well. I propose, therefore, to devote the remainder of my space to its answer, rather than to the practical rules for using the smaller instruments, especially, too, as they have been already introduced to the public, both by my friend Mr. Rand Capron, in his pamphlet "A plea for the Rain-band," and by myself, in the fourteenth volume of the "Edinburgh Astronomical Observations"; also in the "Journal of the Scottish Meteorological Society," and in the September number of the "Astronomical Register for 1877."

The greater part of higher power spectroscopes are not suitable to rain-band work, for their fields are usually too dark. But having recently built up for myself a large-sized variety of the instrument, possessing perhaps the greatest combination of power with transparency yet attained, and having it always mounted in an upper chamber looking out at an altitude of about 5° over the northwestern horizon (or most suitably for rain-band work), I will try to describe shortly its action therein.

The classical "rain-band," which in the little instrument is merely a very narrow fringe to an almost infinitely thin black line, is so magnified laterally in the larger instrument as to fill the whole breadth of the field. The thin black line before spoken of is now not only split into two, but these are both strong, thick, sharply defined lines, separated from each other by six or seven times the breadth of either. These are the celebrated solar D-lines, D1 and D2, arising from the sodium metalloid burning or incandescent in the sun. They are, therefore, perfectly uninfluenced by changes of the terrestrial atmosphere, hot or cold, wet or dry, and are, therefore, invaluable as references for degrees of visibility of the water-vapor lines and bands which rise or fall in intensity precisely with those changes. There are several of these earthly water-vapor lines and bands in and between and about the D-lines themselves; then a long breadth of band toward the red side of D1; then a pair of lines not so widely apart as the D-lines, but sometimes just as sharp and black; then two or three fainter bands; then a grand triple, of which the nearer line sometimes attains greater blackness than either D-line; then beyond that three distinct, equal-spaced, isolated bands; and, farther away toward the red, a stretch of faint haze and haze-bands.

All these go to make up the one thin rain-band of the little spectroscopes; and I fortunately had, through the month of August and

the early days of September, occupied myself each morning in noting the greater or less intensity of each and all these water-vapor lines and bands in terms of the two solar constants D1 and D2; and every such morning there was an abundance of details to see, to recognize, and to measure. But on the morning of Monday, September 4th, when the little instrument had truly enough marked 0 on its very small scale, I almost started at finding in the large instrument every member of its long rain-band group, unless it were a vanishing trace of one or two of the strongest, utterly gone; while the two D-lines were in their accustomed strength, but far greater clearness, for now they were all alone in the field save the ultra-thin solar nickel line between them and one or two others, equally thin and solar on their blue side. The stages of perceptible shade of water-vapor lines which had thus been swept away, between their this day's invisibility, and their tremendous strength no longer before than the previous Friday, might have been expressed by a scale not divided into three parts only, but into thirty; and implied such a very unusual amount of absence of water-vapor that I not only felt sure of no rain falling either next day, or perhaps for several days after, but that the weather must also be coming on colder as well. Therefore it was that I took the step of instantly writing as I did to a local paper, promising the perplexed farmers dry weather at last, though probably sharp and cold, to get in their crops.

And how was that expectation fulfilled? Various meteorologists in different parts of the country have already declared themselves well satisfied with it. But I would now beg further attention to the little daily register already quoted, showing that from and including that day, Monday, September 4th, up to and including the next Saturday, not a drop of rain fell at the observatory. Between the following Sunday and Monday, a drizzle, but only amounting to 0.04 inch, occurred, and after that there were three more days equally dry with the preceding ones. But on Thursday, the 14th, the rain-band re-appeared in both spectroscopes in all its force; rain began to fall the same day, and next day's measure at the observatory amounted to more than half an inch. Wherefore it is to be hoped that the farmers had busied themselves effectively while the dry weather lasted, for the return of these spectral lines of watery vapor showed that their autumn opportunity was then gone by.—*London Times.*

SCIENCE IN RELATION TO THE ARTS.*

By C. William Siemens, F. R. S.

Since the days of the first meeting of the Association in York, in 1831, great changes have taken place in the means at our disposal for exchanging views, either personally or through the medium of type. The creation of the railway system has enabled congenial minds to attend frequent meetings of those special societies which have sprung into existence since the foundation of the British Association, amongst which I need only name here the Physical, Geographical, Meteorological, Anthropological and Linnean, cultivating abstract science, and the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, the Society of Telegraph Engineers and Electricians, the Gas Institute, the Sanitary Institute and the Society of Chemical Industry, representing applied science. These meet at frequent intervals in London, whilst others, having similar objects in view, hold their meetings at the University towns, and at other centres of intelligence and industry throughout the country, giving evidence of great mental activity, and producing some of those very results which the founders of the British Association wished to see realized. If we consider further the extraordinary development of scientific journalism which has taken place, it cannot surprise us when we meet with expressions of opinion to the effect that the British Association has fulfilled its mission, and should now yield its place to those special societies it has served to call into existence. On the other hand, it may be urged that the brilliant success of last year's anniversary meeting, enhanced by the comprehensive address delivered on that occasion by my distinguished predecessor in office, Sir John Lubbock, has proved, at least, that the British Association is not dead in the affections of its members, and it behoves us at this, the first ordinary gathering in the second half century, to consider what are the strong points to rely upon for the continuance of a career of success and usefulness.

If the facilities brought home to our doors, of acquiring scientific

* Presidential Address delivered at the 54th Annual Meeting of the British Association for the Advancement of Science, held at Southampton, August 23d, 1882.

information, have increased, the necessities for scentific inquiry have increased in a greater ratio. The time was when science was cultivated only by the few, who looked upon its application to the arts and manufactures as almost beneath their consideration ; this they were content to leave in the hands of others, who, with only commercial aims in view, did not aspire to further the objects of science for its own sake, but thought only of benefitting by its teachings. Progress could not be rapid under this condition of things, because the man of pure science rarely pursued his inquiry beyond the mere enunciation of a physical or chemical principle, whilst the simple practitioner was at a loss how to harmonize the new knowledge with the stock of information which formed his mental capital in trade.

The advancement of the last fifty years has, I venture to submit, rendered theory and practice so interdependent that an intimate union between them is a matter of absolute necessity for our future progress. Take, for instance, the art of dyeing, and we find that the discovery of new coloring matters derived from waste products, such as coal tar, completely changes its practice, and renders an intimate knowledge of the science of chemistry a matter of absolute necessity to the practitioner. In telegraphy, and in the new arts of applying electricity to lighting, to the transmission of power, and to metallurgical operations, problems arise at every turn, requiring for their solution not only an intimate acquaintance with, but a positive advance upon, electrical science, as established by purely theoretical research in the laboratory. In general engineering, the mere practical art of constructing a machine so designed and proportioned as to produce mechanically the desired effect, would suffice no longer. Our increased knowledge of the nature of the mutual relations between the different forms of energy makes us see clearly what are the theoretical limits of effect; these, although beyond our absolute reach, may be looked upon as the asymptotes to be approached indefinitely by the hyperbolic course of practical progress, of which we should never lose sight. Cases arise, moreover, where the introduction of new materials of construction, or the call for new effects, renders former rules wholly insufficient. In all these cases practical knowledge has to go hand in hand with advanced science in order to accomplish the desired end.

Far be it from me to think lightly of the ardent students of nature, who, in their devotion to research, do not allow their minds to travel into the regions of utilitarianism and of self-interest. These, the high

priests of science, command our utmost admiration; but it is not to them that we can look for our current progress in practical science, much less can we look for it to the "rule of thumb" practitioner, who is guided by what comes nearer to instinct than to reason. It is to the man of science, who also gives attention to practical questions, and to the practitioner, who devotes part of his time to the prosecution of strictly scientific investigations, that we owe the rapid progress of the present day, both merging more and more into one class, that of pioneers in the domain of nature. It is such men that Archimedes must have desired when he refused to teach his disciples the art of constructing his powerful ballistic engines, exhorting them to give their attention to the principles involved in their construction, and that Telford, the founder of the Institution of Civil Engineers, must have had in his mind's eye, when he defined civil engineering as "the art of directing the great sources of power in nature."

These considerations may serve to show that, although we see the men of both abstract and applied science group themselves in minor bodies for the better prosecution of special objects, the points of contact between the different branches of knowledge are ever multiplying, all tending to form part of a mighty tree—the tree of modern science—under whose ample shadow its cultivators will find it both profitable and pleasant to meet, at least once a year; and considering that this tree is not the growth of one country only, but spreads both its roots and branches far and wide, it appears desirable that at these yearly gatherings other nations should be more fully represented than has hitherto been the case. The subjects discussed at our meetings are without exception of general interest, but many of them bear an international character, such as the systematic collection of magnetic, astronomical, meteorological, and geodetical observations, the formation of a universal code for signaling at sea, and for distinguishing lighthouses, and especially the settlement of scientific nomenclatures and units of measurement, regarding all of which an international accord is a matter of the utmost practical importance.

As regards the measures of length and weight it is to be regretted that this country still stands aloof from the movement initiated in France towards the close of last century; but, considering that in scientific work metrical measure is now almost universally adopted, and that its use has been already legalized in this country, I venture to hope that its universal adoption for commercial purposes will soon follow as a

matter of course. The practical advantages of such a measure to the trade of this country would, I am convinced, be very great, for English goods, such as machinery or metal rolled to current sections, are now almost excluded from the continental market, owing to the unit measure employed in their production. The principal impediment to the adoption of the metre consists in the strange anomaly that although it is legal to use that measure in commerce, and although a copy of the standard metre is kept in the Standards' Department of the Board of Trade, it is impossible to procure legalized rods representing it, and to use a non-legalized copy of a standard in commerce is deemed fraudulent. Would it not be desirable that the British Association should endeavor to bring about the use in this country of the metre and kilogram, and, as a preliminary step, petition the government to be represented on the International Metric Commission, whose admirable establishment at Sèvres possesses, independently of its practical work, considerable scientific interest, as a well-found laboratory for developing methods of precise measurement?

Next in importance to accurate measures of length, weight, and time, stand, for the purposes of modern science, those of electricity.

The remarkably clear lines separating conductors from non-conductors of electricity, and magnetic from non-magnetic substances, enable us to measure electrical quantities and effects with almost mathematical precision; and, although the ultimate nature of this, the youngest scientifically investigated form of energy, is yet wrapped in mystery, its laws are the most clearly established, and its measuring instruments (galvanometers, electrometers, and magnetometers) are amongst the most accurate in physical science. Nor could any branch of science or industry be named in which electrical phenomena do not occur, to exercise their direct and important influence.

If, then, electricity stands foremost amongst the exact sciences, it follows that its unit measures should be determined with the utmost accuracy. Yet, twenty years ago very little advance had been made towards the adoption of a rational system. Ohm had, it is true, given us the fixed relations existing between electromotive force, resistance and quantity of current; Joule had established the dynamical equivalent of heat and electricity, and Gauss and Weber had proposed their elaborate system of absolute magnetic measurement. But these invaluable researches appeared only as isolated efforts, when, in 1862, the Electric Unit Committee was appointed by the British Association, at

the instance of Sir William Thomson, and it is to the long-continued activity of this committee that the world is indebted for a consistent and practical system of measurement, which, after being modified in details, received universal sanction last year by the International Electrical Congress assembled at Paris.

At this Congress, which was attended officially by the leading physicists of all civilized countries, the attempt was successfully made to bring about a union between the statical system of measurement that had been followed in Germany and some other countries, and the magnetic or dynamical system developed by the British Association, also between the geometrical measure of resistance, the (Werner) Siemens unit that had been generally adopted abroad, and the British Association unit intended as a multiple of Weber's absolute unit, though not entirely fulfilling that condition. The Congress, while adopting the absolute system of the British Association, referred the final determination of the unit measure of resistance to an International Committee, to be appointed by the representatives of the several governments; they decided to retain the mercury standard for reproduction and comparison, by which means the advantages of both systems are happily combined, and much valuable labor is utilized; only, instead of expressing electrical quantities directly in absolute measure, the Congress has embodied a consistent system, based on the Ohm, in which the units are of a value convenient for practical measurements. In this, which we must hereafter know as the "practical system," as distinguished from the "absolute system," the units are named after leading physicists, the Ohm, Ampère, Volt, Coulomb, and Farad.

I would venture to suggest that two further units might, with advantage, be added to the system decided on by the International Congress at Paris. The first of these is the unit of magnetic quantity or pole. It is of much importance, and few will regard otherwise than with satisfaction tke suggestion of Clausius that the unit should be called a "Weber," thus retaining a name most closely connected with electrical measurements, and only omitted by the Congress in order to avoid the risk of confusion in the magnitude of the unit current with which his name has been formerly associated.

The other unit I should suggest adding to the list is that of power. The power conveyed by a current of an Ampère through the difference of potential of a Volt is the unit consistent with the practical system. It might be appropriately called a Watt, in honor of that master mind

in mechanical science, James Watt. He it was who first had a clear physical conception of power, and gave a rational method of measuring it. A Watt, then, expresses the rate of an Ampère multiplied by a Volt, whilst a horse-power is 746 Watts, and a Cheval de Vapeur 735.

The system of electro-magnetic units would then be:

(1) Weber, the unit of			magnetic quantity	$=10^8$	C.G.S. Units.
(2) Ohm	"	"	resistance	$=10^9$	"
(3) Volt	"	"	electromotive force	$=10^8$	"
(4) Ampère	"	"	current	$=10^{-1}$	"
(5) Coulomb	"	"	quantity	$=10^{-1}$	"
(6) Watt	"	"	power	$=10^7$	"
(6) Farad	"	"	capacity	$=10^{-9}$	"

Before the list can be looked upon as complete two other units may have to be added, the one expressing that of magnetic field, and the other of heat in terms of the electro-magnetic system. Sir William Thomson suggested the former at the Paris Congress, and pointed ont that it would be proper to attach to it the name of Gauss, who first theoretically and practically reduced observations of terrestrial magnetism to absolute measure. A Gauss will, then, be defined as the intensity of field produced by a Weber at a distance of one centimetre; and the Weber will be the absolute C.G.S. unit strength of magnetic pole. Thus the mutual force between two ideal point-poles, each of one Weber strength held at unit distance asunder, will be one dyne; that is to say, the force which, acting for a second of time on a gram of matter, generates a velocity of one centimetre per second.

The unit of heat has hitherto been taken variously as the heat required to raise a pound of water at the freezing point through 1° Fahrenheit or Centigrade, or, again, the heat necessary to raise a kilogram of water 1° Centigrade. The inconvenience of a unit so entirely arbitrary is sufficiently apparent to justify the introduction of one based on the electro-magnetic system, viz., the heat generated in one second by the current of an Ampère flowing through the resistance of an Ohm. In absolute measure its value is 10^7 C.G.S. units, and, assuming Joule's equivalent as 42,000,000, it is the heat necessary to raise 0·238 grams of water 1° Centigrade, or, approximately, the $\frac{1}{1000}$ part of the arbitrary unit of a pound of water raised 1° Fahrenheit and the $\frac{1}{4000}$ of the kilogramme of water raised 1° Centigrade. Such a heat unit, if found acceptable, might with great propriety, I

think, be called the Joule, after the man who has done so much to develop the dynamical theory of heat.

Professor Clausius urges the advantages of the statical system of measurement for simplicity, and shows that the numerical values of the two systems can readily be compared by the introduction of a factor, which he proposes to call the critical velocity; this, Weber has already shown to be nearly the same as the velocity of light. It is not immediately evident how by the introduction of a simple multiple, signifying a velocity, the statical can be changed into dynamical values, and I am indebted to my friend Sir William Thomson for an illustration which struck me as remarkably happy and convincing. Imagine a ball of conducting matter so constituted that it can at pleasure be caused to shrink. Now let it first be electrified and left insulated with any quantity of electricity on it. After that, let it be connected with the earth by an excessively fine wire or a not perfectly dry silk fibre; and let it shrink just so rapidly as to keep its potential constant, till the whole charge is carried off. The velocity with which its surface approaches its centre is the electrostatic measure of the conducting power of the fibre. Thus we see how "conducting power" is, in electostatic theory, properly measured in terms of a velocity. Weber had shown how, in electro-magnetic theory, the resistance, or the reciprocal of the conducting power of a conductor, is properly measured by a velocity. The critical velocity, which measures the conducting power in electrostatic reckoning and the resistance in electromagnetic, of one and the same conductor, measures the number of electrostatic units in the electromagnetic unit of electric quantity.

Without waiting for the assembling of the International Committee charged with the final determination of the Ohm, one of its most distinguished members, Lord Rayleigh, has, with his collaborateure, Mrs. Sidgwick, continued his important investigation in this direction at the Cavendish Laboratory, and has lately placed before the Royal Society a result which will probably not be surpassed in accuracy. His redetermination brings him into close accord with Dr. Werner Siemens, their two values of the mercury unit being 0·95418 and 0·9536 of the B.A. unit respectively, or 1 mercury unit $= 0{\cdot}9413 \times 10^9$ C.G.S. units.

Shortly after the publication of Lord Rayleigh's recent results, Messrs. Glazebrook, Dodds, and Sargant, of Cambridge, communicated to the Royal Society two determinations of the Ohm, by different

methods; and it is satisfactory to find that their final values differ only in the fourth decimal, the figures being, according to

$$\text{Lord Rayleigh,} \quad . \quad . \quad 1 \text{ Ohm} = 0{\cdot}98651 \frac{\text{Earth Quadrant.}}{\text{Second.}}$$

$$\text{Messrs. Glazebrook, etc.,} \qquad = 0{\cdot}986439 \qquad \text{“}$$

Professor E. Wiedemann, of Leipzig, has lately called attention to the importance of having the Ohm determined in the most accurate manner possible, and enumerates four distinct methods, all of which should unquestionably be tried with a view of obtaining concordant results, because upon its accuracy will depend the whole future system of measurement of energy of whatever form.

The word Energy was first used by Young in a scientific sense, and represents a conception of recent date, being the outcome of the labors of Carnot, Mayer, Joule, Grove, Clausius, Clerk-Maxwell, Thomson, Stokes, Helmholtz, Macquorn-Rankine, and other laborers, who have accomplished for the science regarding the forces in Nature what we owe to Lavoisier, Dalton, Berzelius, Liebig, and others, as regards Chemistry. In this short word Energy we find all the efforts in nature, including electricity, heat, light, chemical action, and dynamics, equally represented, forming, to use Dr. Tyndall's apt expression, so many "modes of motion." It will readily be conceived that when we have established a fixed numerical relation between these different modes of motion we know beforehand what is the utmost result we can possibly attain in converting one form of energy into another, and to what extent our apparatus for effecting the conversion falls short of realizing it. The difference between ultimate theoretical effect and that actually obtained is commonly called loss, but, considering that energy is indestructible, represents really secondary effect which we obtain without desiring it. Thus friction in the working parts of a machine represents a loss of mechanical effect, but is a gain of heat, and in like manner the loss sustained in transferring electrical energy from one point to another is accounted for by heat generated in the conductor. It sometimes suits our purpose to augment the transformation of electrical into heat energy at certain points of the circuit when the heat rays become visible, and we have the incandescence electric light. In effecting a complete severance of the conductor for a short distance, after the current has been established, a very great local resistance is occasioned, giving rise to the electric arc, the highest development of heat ever attained. Vibration is another form of lost

energy in mechanism, but who would call it a loss if it proceeded from the violin of a Joachim or a Norman-Neruda?

Electricity is the form of energy best suited for transmitting an effect from one place to another; the electric current passes through certain substances—the metals—with a velocity limited only by the retarding influence caused by electric charge of the surrounding dielectric, but approaching probably under favorable conditions that of radiant heat and light, or 300,000 kilometres per second; it refuses, however, to pass through oxidized substances, glass, gums, or through gases except when in a highly rarefied condition. It is easy therefore, to confine the electric current within bounds, and to direct it through narrow channels of extraordinary length. The conducting wire of an Atlantic cable is such a narrow channel, it consists of a copper wire, or strand of wires, 5 mm. in diameter, by nearly 5,000 kilometres in length, confined electrically by a coating of guttapercha about 4 mm. in thickness. The electricity from a small galvanic battery passing into this channel prefers the long journey to America in the good conductor, and back through the earth, to the shorter journey across the 4 mm. in thickness of insulating material. By an improved arrangement the alternating currents employed to work long submarine cables do not actually complete the circuit, but are merged in a condenser at the receiving station after having produced their extremely slight but certain effect upon the receiving instrument, the beautiful syphon recorder of Sir William Thomson. So perfect is the channel and so precise the action of both the transmitting and receiving instruments employed, that two systems of electric signals may be passed simultaneously through the same cable in opposite directions, producing independent records at either end. By the application of this duplex mode of working to the direct United States cable under the superintendence of Dr. Muirhead, its transmitting power was increased from twenty-five to sixty words a minute, being equivalent to about twelve currents or primary impulses per second. In transmitting these impulse-currents simultaneously from both ends of the line, it must not be imagined, however, that they pass each other in th manner of liquid waves belonging to separate systems; such a suppositon would involve momentum in the electric flow, and although the effect produced is analagous to such an action, it rests upon totally different grounds—namely, that of a local circuit at each terminus being called into action automatically whenever two similar currents are passed into the line simultaneously

from both ends. In extending this principle of action quadruplex telegraphy has been rendered possible, although not yet for long submarine lines.

The minute currents here employed are far surpassed as regards delicacy and frequency by those revealed to us by that marvel of the present day, the telephone. The electric currents caused by the vibrations of a diaphragm acted upon by the human voice naturally vary in frequency and intensity according to the number and degree of those vibrations, and each motor current in exciting the electromagnet forming part of the receiving instrument, deflects the iron diaphragm occupying the position of an armature to a greater or smaller extent according to its strength. Savart found that the fundamental *la* springs from 440 complete vibrations in a second, but what must be the frequency and modulations of the motor current and of magnetic variations necessary to convey to the ear through the medium of a vibrating armature such a complex of human voices and of musical instruments as constitutes an opera performance. And yet such performances could be distinctly heard and even enjoyed as an artistic treat by applying to the ears a pair of the double telephonic receivers at the Paris Electrical Exhibition, when connected with a pair of transmitting instruments in front of the footlights of the Grand Opera. In connection with the telephone, and with its equally remarkable adjunct, the microphone, the names of Riess, Graham Bell, Edison, and Hughes will ever be remembered.

Considering the extreme delicacy of the currents working a telephone, it is obvious that those caused by induction from neighboring telegraphic line wires would seriously interfere with the former, and mar the speech or other sounds produced through their action. To avoid such interference the telephone wires if suspended in the air require to be placed at some distance from telegraphic line wires, and to be supported by separate posts. Another way of neutralizing interference consists in twisting two separately insulated telephone wires together so as to form a strand, and in using the two conductors as a metallic circuit to the exclusion of the earth; the working current will, in that case receive equal and opposite inductive influences, and will therefore remain unaffected by them. On the other hand, two insulated wires instead of one are required for working one set of instruments, and a serious increase in the cost of installation is thus caused. To avoid this Mr. Jacob has lately suggested a plan of combining

pairs of such metallic circuits again into separate working pairs, and these again with other working pairs, whereby the total number of telephones capable of being worked without interference is made to equal the total number of single wires employed. The working of telephones and telegraphs in metallic circuit has the further advantage that mutual volta induction between the outgoing and returning currents favors the transit, and neutralizes on the other hand the retrading influence caused by charge in underground or submarine conductors. These conditions are particularly favorable to underground line wires, which possess other important advantages over the still prevailing overground system, in that they are unaffected by atmospheric electricity, or by snow storms and heavy gales, which at not very rare intervals of time put us back to pre-telegraphic days, when the letter carrier was our swiftest messenger.

The undergroung system of telegraphs, first introduced into Germany by Werner Siemens in the years 1847–8, had to yield for a time to the overground system owing to technical difficulties, but it has been again resorted to within the last four years, and multiple land cables of solid construction now connect all the important towns of that country. The first cost of such a system is no doubt considerable, being about 38*l.* per kilometre of conductor as against 8*l.* 10*s.* the cost of land lines); but as the underground wires are exempt from frequent repairs and renewals, and as they insure continuity of service, they are decidedly the cheaper and better in the end. The experience afforded by the early introduction of the underground system in Germany was not, however, without its beneficial results, as it brought to light the phenomena of lateral induction, and of faults in the insulating coating, matters which had to be understood before submarine telegrephy could be attempted with any reasonable prospect of success.

Regarding the transmission of power to a distance, the electric current has now entered the lists in competition with compressed air, the hydraulic accumulator, and the quick running rope as used at Schaffhausen to utilize the power of the Rhine fall. The transformation of electrical into mechanical energy can be accomplished with no further loss than is due to such incidental causes as friction and the heating of wires; these in a properly designed dynamo-electric machine do not exceed ten per cent., as shown by Dr. John Hopkinson, and, judging from recent experiments of my own, a still nearer approach to ultimate perfection is attainable. Adhering, however, to Dr. Hopkin-

son's determination for safety's sake, and assuming the same percentage in reconverting the current into mechanical effect, a total loss of 19 per cent. results. To this loss must be added that through electrical resistance in the connecting line wires, which depends upon their length and conductivity, and that due to heating by friction of the working parts of the machine. Taking these as being equal to the internal losses incurred in the double process of conversion, there remains a useful effect of 100—38=62 per cent. attainable at a distance, which agrees with experimental results, although in actual practice it would not be safe at present to expect more than 50 per cent. of ultimate useful effect, to allow for all mechanical losses.

In using compressed air or water for the transmission of power the loss cannot be taken at less than fifty per cent., and as it depends upon fluid resistance it increases with distance more rapidly than in the case of electricity. Taking the loss of effect in all cases as 50 per cent. electric transmission presents the advantage that an insulated wire does the work of a pipe capable of withstanding high internal pressure, which latter must be more costly to put down and to maintain. A second metallic conductor is required, however, to complete the electrical circuit, as the conducting power of the earth alone is found unreliable for passing quantity currents, owing to the effects of polarization; but as this second conductor need not be insulated, water or gas pipes, railway metals or fencing wire, may be called into requisition for the purpose. The small space occupied by the electro-motor, its high working speed, and the absence of waste products, render it specially available for the general distribution of power to cranes and light machinery of every description. A loss of effect of 50 per cent. does not stand in the way of such applications, for it must be remembered that a powerful central engine of best construction produces motive power with a consumption of two pounds of coal per horse-power per hour, whereas small engines distributed over a district would consume not less than five; we thus see that there is an advantage in favour of electric transmission as regards fuel, independently of the saving of labor and other collateral benefits.

To agriculture electric transmission of power seems well adapted for effecting the various operations of the farm and fields from one centre. Having worked such a system myself in combination with electric lighting and horticulture for upwards of two years, I can speak with

confidence of its economy, and of the facility with which the work is accomplished in charge of untrained persons.

As regards the effect of the electric light upon vegetation there is little to add to what was stated in my paper read before Section A last year, and ordered to be printed with the report, except that in experimenting upon wheat, barley, oats, and other cereals sown in the open air, there was a marked difference between the growth of the plants influenced and those uninfluenced by the electric light. This was not very apparent till towards the end of February, when, with the first appearance of mild weather, the plants under the influence of an electric lamp of 4000 candle power placed about 5 metres above the surface, developed with extreme rapidity, so that by the end of May they stood above 4 feet high, with the ears in full bloom, when those not under its influence were under 2 feet in height, and showed no sign of the ear.

In the electric railway first constructed by Dr. Werner Siemens, at Berlin, in 1879, electric energy was transmitted to the moving carriage or train of carriages through the two rails upon which it moved, these being sufficiently insulated from each other by being placed upon well creosoted cross sleepers. At the Paris Electrical Exhibition the current was conveyed through two separate conductors making sliding or rolling contact with the carriage, whereas in the electric railway now in course of construction in the north of Ireland (which when completed will have a length of twelve miles) a separate conductor will be provided by the side of the railway, and the return circuit completed through the rails themselves, which in that case need not be insulated; secondary batteries will be used to store the surplus energy created in running downhill, to be restored in ascending steep inclines, and for passing roadways where the separate insulated conductor is not practicable. The electric railway possesses great advantages over horse or steam-power for towns, in tunnels, and in all cases where natural sources of energy, such as waterfalls, are available; but it would not be reasonable to suppose that it will in its present condition compete with steam propulsion upon ordinary railways. The transmission of power by means of electric conductors possesses the further advantage over other means of transmission that, provided the resistance of the rails be not very great, the power communicated to the locomotive reaches its maximum when the motion is at its minimum—that is, in commencing to work, or when encountering an exceptional resistance—whereas the

utmost economy is produced in the normal condition of working when the velocity of the power-absorbing nearly equals that of the current-producing machine.

The deposition of metals from their solutions is perhaps the oldest of all useful applications of the electric current, but it is only in very recent times that the dynamo current has been practically applied to the refining of copper and other metals, as now practised at Birmingham and elsewhere, and upon an exceptionally large scale at Ocker, in Germany. The dynamo machine there employed was exhibited at the Paris Electrical Exhibition by Dr. Werner Siemens, its peculiar feature being that the conductors upon the rotating armature consisted of solid bars of copper 30 mm. square in section, which were found only just sufficient to transmit the large quantity of electricity of low tension necessary for this operation. One such machine consuming 4 horse-power deposits about 300 kilogrammes of copper per 24 hours; the motive power at Ocker is derived from a waterfall.

Electric energy may also be employed for heating purposes, but in this case it would obviously be impossible for it to compete in point of economy with the direct combustion of fuel for the attainment of ordinary degrees of heat. Bunsen and St. Claire De Ville have taught us, however, that combustion becomes extremely sluggish when a temperature of 1800°C. has been reached, and for effects at temperatures exceeding that limit the electric furnace will probably find advantageous applications. Its specific advantage consists in being apparently unlimited in the degree of heat attainable, thus opening out a new field of investigation to the chemist and metallurgist. Tungsten has been melted in such a furnace, and 8 pounds of platinum have been reduced from the cold to the liquid condition in 20 minutes.

The largest and most extensive application of electric energy at the present time is to lighting, but considering how much has of late been said and written for and against this new illuminant, I shall here confine myself to a few general remarks. Joule has shown that if an electric current is passed through a conductor the whole of the energy lost by the current is converted into heat; or, if the resistance be localized, into radiant energy comprising heat, light, and actinic rays. Neither the low heat rays nor the ultra-violet of highest refrangibility affect the retina, and may be regarded as lost energy, the effective rays being those between the red and violet of the spectrum, which in their combination produce the effect of white light.

Regarding the proportion of luminous to non-luminous rays proceeding from an electric arc or incandescent wire, we have a most valuable investigation by Dr. Tyndall, recorded in his work on "Radiant Heat." Dr. Tyndall shows that the luminous rays from a platinum wire heated to its highest point of incandescence, which may be taken at 1700°C., formed $\frac{1}{24}$ part of the total radiant energy emitted, and $\frac{1}{10}$ part in the case of an arc light worked by a battery of 50 Grove's elements. In order to apply these valuable data to the case of electric lighting by means of dynamo-currents, it is necessary in the first place to determine what is the power of 50 Grove's elements of the size used by Dr. Tyndall, expressed in the practical scale of units as now established. From a few experiments, lately undertaken for myself, it would appear that 50 such cells have an electro-motive force of 98·5 Volts, and an internal resistance of 13·5 Ohms, giving a current of 7·3 Ampères when the cells are short-circuited. The resistance of a regulator such as Dr. Tyndall used in his experiments may be taken at 10 Ohms, the current produced in the arc would be $\frac{98{\cdot}5}{13{\cdot}5+10+1}=4$ Ampères (allowing one Ohm for the leads), and the power consumed $10\times4^2=160$ Watts; the light power of such an arc would be about 150 candles, and, comparing this with an arc of 3308 candles produced by 1162 Watts, we find that $\left(\frac{1162}{160}\right)$, *i. e.*, 7·3 times the electric energy produce $\left(\frac{3308}{150}\right)$, *i. e.*, 22 times the amount of light measured horizontally. If, therefore, in Dr. Tyndall's arc $\frac{1}{10}$ of the radiant energy emitted was visible as light, it follows that in a powerful arc of 3300 candles, $\frac{1}{10}\times\frac{22{\cdot}0}{7{\cdot}3}$, or fully $\frac{1}{3}$, are luminous rays. In the case of the incandescence light (say a Swan light of 20 candle power) we find in practice that 9 times as much power has to be expended as in the case of the arc light; hence $\frac{1}{3}\times\frac{1}{9}=\frac{1}{27}$ part of the power is given out as luminous rays, as against $\frac{1}{24}$ in Dr. Tyndall's incandescent platinum—a result sufficiently approximate considering the wide difference of conditions under which the two are compared.

These results are not only of obvious practical value, but they seem to establish a fixed relation between current, temperature, and light produced, which may serve as a means to determine temperatures exceeding the melting point of platinum with greater accuracy than has hith-

erto been possible by actinimetric methods in which the thickness of the luminous atmosphere must necessarily exercise a disturbing influence. It is probably owing to this circumstance that the temperature of the electric arc as well as that of the solar photosphere has frequently been greatly over-estimated.

The principal argument in favor of the electric light is furnished by its immunity from products of combustion which not only heat the lighted apartments, but substitute carbonic acid and deleterious sulphur compounds for the oxygen upon which respiration depends; the electric light is white instead of yellow, and thus enables us to see pictures, furniture, and flowers as by daylight; it supports growing plants instead of poisoning them, and by its means we can carry on photography and many other industries at night as well as during the day. The objection frequently urged against the electric light, that it depends upon the continuous motion of steam or gas engines, which are liable to accidental stoppage, has been removed by the introduction into practical use of the secondary battery; this, although not embodying a new conception, has lately been greatly improved in power and constancy by Planté, Faure, Volckmar, Sellon, and others, and promises to accomplish for electricity what the gas-holder has done for the supply of gas and the accumulator for hydraulic transmission of power.

It can no longer be a matter of reasonable doubt, therefore, that electric lighting will take its place as a public illuminant, and that even though its cost should be found greater than that of gas, it will be preferred for the lighting of drawing-rooms and dining-rooms, theatres and concert-rooms, museums, churches, warehouses, show rooms, printing establishments and factories, and also the cabins and engine-rooms of passenger steamers. In the cheaper and more powerful form of the arc light it has proved itself superior to any other illuminant for spreading artificial daylight over the large areas of harbors, railway stations, and the sites of public works. When placed within a holophote the electric lamp has already become a powerful auxiliary in effecting military operations both by sea and land.

The electric light may be worked by natural sources of power such as waterfalls, the tidal wave, or the wind, and it is conceivable that these may be utilized at considerable distances by means of metallic conductors. Some five years ago I called attention to the vastness of those sources of energy, and the facility offered by electrical conduction in rendering them available for lighing and power-supply, while Sir

William Thomson made this important matter the subject of his admirable address to Section A last year at York, and dealt with it in an exhaustive manner.

The advantages of the electric light and of the distribution of power by electricity have lately been recognized by the British government, who have just passed a bill through parliament to facilitate the establishment of electrical conductors in town, subject to certain regulating clauses to protect the interests of the public and of local authorities. Assuming the cost of electric light to be practically the same as gas, the preference for one or other will in each application be decided upon grounds of relative convenience, but I venture to think that gas-lighting will hold its own as the poor man's friend.

Gas is an institution of the utmost value to the artisan; it requires hardly any attention, is supplied upon regulated terms, and gives with what should be a cheerful light a genial warmth, which often saves the lighting of a fire. The time is moreover not far distant, I venture to think, when both rich and poor will largely resort to gas as the most convenient, the cleanest, and the cheapest of heating agents, and when raw coal will be seen only at the colliery or the gas works. In all cases where the town to be supplied is within say 30 miles of the colliery, the gas works may with advantage be planted at the mouth, or still better at the bottom of the pit, whereby all haulage of fuel would be avoided, and the gas, in its ascent from the bottom of the colliery, would acquire an onward pressure sufficient probably to impel it to its destination. The possibility of transporting combustible gas through pipes for such a distance has been proved at Pittsburg, where natural gas from the oil district is used in large quantities.

The quasi monopoly so long enjoyed by gas companies has had the inevitable effect of checking progress. The gas being supplied by meter, it has been seemingly to the advantage of the companies to give merely the prescribed illuminating power, and to discourage the invention of economical burners, in order that the consumption might reach a maximum. The application of gas for heating purposes has not been encouraged, and is still made difficult in consequence of the objectionable practice of reducing the pressure in the mains during day-time to the lowest possible point consistent with prevention of atmospheric indraught. The introduction of the electric light has convinced gas managers and directors that such a policy is no longer tenable, but must give way to one of technical progress; new processes for cheap-

ening the production and increasing the purity and illuminating power of gas are being fully discussed before the Gas Institute; and improved burners, rivaling the electric light in brilliancy, greet our eyes as we pass along our principal thoroughfares.

Regarding the importance of the gas supply as it exists at present, we find from a government return that the capital invested in gas works in England, other than those of local authorities, amounts to 30,000,000*l.*; in these 4,281,048 tons of coal are converted annually, producing 43,000 million cubic feet of gas, and about 2,800,000 tons of coke; whereas the total amount of coal annually converted in the United Kingdom may be estimated at 9,000,000 tons, and the by-products therefrom at 500,000 tons of tar, 1,000,000 tons of ammonia liquor, and 4,000,000 tons of coke, according to the returns kindly furnished me by the managers of many of the gas works and corporations. To these may be added say 120,000 tons of sulphur, which up to the present time is a waste product.

Previous to the year 1856—that is to say, before Mr. W. H. Perkin had invented his practical process, based chiefly upon the theoretical investigations of Hoffman, regarding the coal-tar bases and the chemical constitution of indigo—the value of coal-tar in London was scarcely a half-penny a gallon, and in country places gas-makers were glad to give it away. Up to that time the coal-tar industry had consisted chiefly in separating the tar by distillation into naphtha, creosote, oils, and pitch. A few distillers, however, made small quantities of benzene, which had been first shown—by Mansfield, in 1849—to exist in coal-tar naphtha mixed with toluene, cumene, etc. The discovery, in 1856, of the mauve or aniline purple gave a great impetus to the coal-tar trade, inasmuch as it necessitated the separation of large quantities of benzene, or a mixture of benzene and toluene, from the naphtha. The trade was further increased by the discovery of the magenta or rosaniline dye, which required the same products for its preparation. In the meantime, carbolic acid was gradually introduced into commerce, chiefly as a disinfectant, but also for the production of coloring matter.

The next most important development arose from the discovery by Græbe and Liebermann that alizarine, the coloring principle of the madder root, was allied to anthracene, a hydrocarbon existing in coal-tar. The production of this coloring matter from anthracene followed, and is now one of the most important operations connected with tar

distilling. The success of the alizarine made in this manner has been so great that it has almost entirely superseded the use of madder, which is now cultivated to only a comparatively small extent. The most important coloring matters recently introduced are the azo-scarlets. They have called into use the coal-tar hydrocarbons, xylene and cumene. Napthalene is also used in their preparation. These splendid dyes have replaced cochineal in many of its applications, and have thus seriously interfered with its use. The discovery of artificial indigo by Professor Baeyer is of great interest. For the preparation of this coloring matter toluene is required. At present artificial indigo does not compete seriously with the natural product; but should it eventually be prepared in quantity from toluene a further stimulus will be given to the coal-tar trade.

The color industry utilizes even now practically all the benzene, a large proportion of the solvent naphtha, all the anthracene, and a portion of the naphthaline resulting from the distillation of coal-tar; and the value of the coloring matter thus produced is estimated by Mr. Perkin at 3,350,000*l*.

(To be continued.)

THE CHEMISTRY OF THE PLANTÉ AND FAURE ACCUMULATORS.*

By J. H. GLADSTONE and ALFRED TRIBE.

PART IV.—THE FUNCTION OF SULPHATE OF LEAD.

In our previous communications on the chemistry of the lead and peroxide batteries we have frequently remarked on the formation of lead sulphate and its importance in the history of a cell.

In Part I (this journal, vol. cxiv, p. 219) we showed that the local action that takes place at first energetically between the metallic lead and the peroxide is gradually diminished by the formation of sulphate of lead.

In Part II (vol. cxiv, p. 223) we stated that in the original formation of a Faure cell, sulphate of lead is oxidated on the one plate and reduced on the other. We also described an experiment in which two platinum plates were covered with lead-sulphate, immersed in dilute

* London *Nature*, Oct. 19, 1882.

sulphuric acid, and placed in the circuit of a galvanic current; the result being that "the white sulphate was decomposed to a large extent on each plate, the positive being covered with deep chocolate-colored peroxide, the negative with gray spongy lead."

In Part III (vol. cxiv, p. 229) we showed that on the discharge of a cell, lead sulphate is the ultimate product on both plates.

It might naturally be inferred from our previous statements that in the recharging of a cell this lead sulphate would be oxidated on the one plate and reduced on the other as in the original formation. This matter, however, has given rise to some controversy. All subsequent experimenters admit the *oxidation* of the lead-sulphate, but Dr. Oliver Lodge could not obtain any reduction of it when pure sulphate was employed. Sir William Thomson also, when experimenting, with two platinum plates and layers of sulphate, obtained only a doubtful indication of reduced metal. The question as to whether the sulphate is reduced or not, on recharging a Faure cell is one of vital importance; for if the sulphate formed at each discharge accumulates on the positive plate it would clog up the space, and, what is perhaps worse, a fresh surface of the lead would have to be oxidated (or rather, converted into sulphate) at each discharge. Thus the positive plate will be continually corroded, and its life will be limited.

We have already replied to Dr. Lodge in *Nature* (vol. xxvi, p. 342), but we thought it desirable to repeat the experiment with the platinum plates, especially with a view to determine whether the reduction was effected slowly or with any rapidity. We fastened 20 grammes of the white sulphate upon a negative plate by binding it round tightly with parchment-paper, placed it vertically in the sulphuric acid, and passed a continuous current of somewhat under an Ampère. The hydrogen was at no time wholly absorbed—indeed the greater part of it certainly escaped—but after the lapse of twenty-four hours, small patches of gray metallic lead became distinctly visible through the wet parchment-paper; and these gradually spread in an irregular manner. At the end of ten days it was found that the whole of the sulphate, except a few small patches on the surface, was reduced to a gray spongy mass. Although there could be no reasonable doubt that this was metallic lead, a portion of it was tested chemically, and proved to be such.

It thus appears that the *reduction* of the pure sulphate of lead is an absolute fact, although it does not take place so easily as the oxidation.

In an actual cell the sulphate of lead is of course mixed with other

bodies. Thus, in the formation of a Faure battery, the minium is converted by the sulphuric acid more or less completely into peroxide of lead and sulphate. We have already described an experiment in which 4489 cc. of hydrogen were absorbed on a plate, the materials of which were capable of absorbing only 4574 cc., if the whole sulphate as well as the peroxide was reduced. In our note-book we have the particulars of four other experiments made in each case with the same, or nearly the same, amount of material, in which 4199, 4575, 4216, and 4387 cc. respectively were absorbed, although perhaps in not one of these cases was the experiment continued until the action was absolutely complete. As, however, it may be objected that the amount of sulphate produced upon these plates was an unknown quantity, we have in a recent experiment treated the minium in the first instance with a considerable amount of sulphuric acid. This gave us a mixture which, on analysis, was found to contain 18·5 per cent. of sulphate of lead. This mixture when submitted to the reducing action of a current yielded a mass of spongy lead that contained only a mere trace of sulphate.

As it seemed desirable fully to establish the fact that the sulphate of lead formed on the discharge of a cell is reduced in the subsequent charging, we took the quondam lead plate of a fully discharged cell, determined the proportion of sulphate to unaltered spongy lead, and submitted it to the reducing action of a current. The amount of sulphate on the plate before passing the current was found to be 51 per cent., but, after the passage of a current, of about an ampère for 60 hours, not a trace of it remained.

Hence it may be concluded that, during the alternate discharging and recharging of a Planté or Faure cell, sulphate of lead is alternately formed and reduced on the lead plate, and that the plate itself is not seriously corroded. It would, however, appear desirable not to allow the whole of the spongy lead to be reduced to sulphate during the discharge for two reasons, viz.: (1) because the supporting plate stands a chance of being itself acted on if there is not a sufficient excess of spongy metal; and (2) because the presence of this excess tends to facilitate the reduction of the sulphate.

We have already shown that sulphate of lead is produced by the local action that takes place between the peroxide and its supporting lead plate during repose. The same local action also takes place during the charging of the plate, as was pointed out in our second

communication, and this sulphate is, in its turn, attacked by the electrolytic oxygen. In this way the absorption of oxygen in forming the negative plate ought never to come to an end. In order to see whether this was the case, we allowed an experiment to continue for 115 hours, although the main action was over in about 40 hours. For the last two days of the experiment, the amount of oxygen absorbed was pretty constant, being about 9 cc. per hour, which is equivalent to 0·24 grammes of sulphate of lead formed and oxidated. The whole charge on the plate was 40 grammes of peroxide. This local action also takes place during the discharge, as is evidenced by the sulphate of lead formed on the negative plate always exceeding in amount that formed on the positive plate.

Through this local action taking place during the formation of the cell, during repose, and during the discharge, the lead plate which supports the peroxide must be continually corroded more and more; and it is probably due to the insolubility of the sulphate formed that the destruction of this kind of secondary battery is so materially retarded in practice.

Contribution of Astronomy to the Solution of a Molecular Problem.—Pictet's consideration of the temperature of a body as resulting from the mean amplitude of its molecular oscillations enables him to explain and deduce all the essential laws of thermodynamics, Dulong and Petit's law, the law of isomorphism in systems of crystallization, the relations which unite coefficients of dilatation with atomic weight, etc. Under this view, specific heat becomes the manifestation of the attraction of molecules for one another; by multiplying the space traversed (temperature) by the molecular force (specific heat) we obtain the total heat or absolute quantity of work which the body contains. Hence, consequently, arises a question of the first importance: Is the mutual attraction of particles of matter a fundamental and essential property of matter itself, or is it only the result of dynamic action of the medium in which it is found? Pictet suggests various astronomical observations which seem likely to contribute to a solution of this question. [Chase's discovery of the velocity of light in the coefficient of solar torsion (*Proc. Am. Phil. Soc.*, April 21, 1882, note 162) points to the photodynamic action of the æthereal medium.]—*Ann. de Chim. et de Phys.*, April, 1882.

The Electric Arc in Vapor of Sulphuret of Carbon.—Jamin and Maneuvrier introduced a few drops of sulphuret of carbon into Geissler tubes, so as slightly to increase the pressure, and thus obtained a light of great brilliancy. On looking at it with smoked glass, they saw a brilliant arc resembling a horse-shoe or a capital omega. The points of the two carbons appeared red and very brilliant; but the arc was of a pale green, and as its light surpassed that of the carbons, the whole hall was illuminated with its tint as it would have been by a copper Bengal light. The brilliancy increased with the increasing tension of the vapor, until it became intolerable; but as the resistance increased at the same time, the arc was often extinguished, and it was necessary frequently to renew it by bringing the two carbons together. It is not likely that the light can be advantageously used, unless for light-houses or signals at a distance.—*Comptes Rendus*, xcv, 6. C.

Surface Temperatures in Paris.—Edmond and Henri Becquerel have presented to the French Academy their observations upon the temperatures of the air and earth during the year 1880. They find that at the upper surface of the ground, when covered with snow, the temperature was maintained almost constantly in the neighborhood of —1°C. and did not fall below—1·5°, although the temperature of the air as well as that of the upper surface of the snow varied from—15° to 0°. The diurnal variations of temperature at the surface of the soil were perceptible under a mass of snow of ·25 metre thickness (9·84 inches), but they never exceed a few tenths of a degree; moreover, the differences in the observed temperatures at different depths in the snow varied nearly in proportion to the depth. These results show that a bed of snow, when the temperature is below 0°C. has a feeble conductivity and behaves like a conducting body traversed by a calorific wave. Under a surface which is covered by turf the variations are much more feeble than under a surface of gravel or loam. The network of rootlets constitutes an almost complete non-conductor. Each bed of soil is submitted to the influence of two calorific effects; one due to the variations of external temperature, the other to the action of the deep layers which tend to produce a constant temperature. The amplitude of thermometric oscillation which results from these complex effects when there is any disturbing influence, such as an infiltration of water, varies inversely with the depth of the bed.—*Comptes Rendus.* C.

The Stone Age in China.—The annals of the Tung dynasty, which was established A. D. 618, speak of stone axes, knives and swords. The annals of the Youen dynasty (A. D. 1260 to 1341) mention soldiers who used stone arrows in fighting. In a Chinese dictionary which was published in 1726 arrows are also spoken of which were pointed by a black stone. Stone arrows were sent to the Emperor Hou Hang, B. C. 1100, and the Chinese books speak of some knives and hatchets of a still greater antiquity.—*Les Mondes*, xxxi, 626. C.

Hydrodynamic Imitation of Electric Phenomena.—Decharme compares the experiments of Bjerknes upon hydro-electricity and hydromagnetism with some observations of his own, in which he substitutes liquid currents, continuous or interrupted, for pulsating or vibrating bodies. By various ingenious contrivances he produces hydro-electro magnets with continuous or discontinuous currents, hydrodynamic vibrations, hydo-electro magnets with similar or with contrary poles and with single or with multiple nuclei manifesting all the phenomena of attraction, repulsion, vibratory movement, hydro-induction and the action of currents upon each other.—*Ann. de Chim. et de Phys.*, April, 1882.

Widening of the Hydrogen Rays.—Lockyer and most astronomers attribute the widening of the spectral rays of hydrogen to the influence of pressure, while others, among whom was Secchi, think that the phenomenon is influenced both by pressure and by temperature. Cailletet, in experimenting upon hydrogen with the electric spark, found that the spectral rays varied somewhat in proportion to the pressure. But as the temperature of the spark increases with the pressure his experiments were inconclusive. The same may be said of the tubes filled with rarefied hydrogen, which were employed by Plücker, Hittorf, Secchi, Wüllner, etc. At a certain pressure, which was differently estimated by each observer, the rays broaden, and they become wider still if the tube is traversed by the spark of the Leyden jar, the temperature of which is more elevated. D. von Monckhoven reports a summary of numerous and varied experiments, from which he draws the conclusion that the widening of the rays is absolutely independent of the temperature and is due solely to the pressure.—*Comptes Rendus*, xcv, 378. C.

Franklin Institute.

Hall of the Institute, December 20, 1882.

The stated meeting of the Institute was held this evening at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

There were present 208 members and 40 visitors.

The minutes of the last stated meeting were read and approved.

The Actuary submitted the miuutes of the Board of Managers, and reported that at the stated meeting held December 13th 11 persons had been elected as members. He likewise reported the resignation of Mr. Frederick Fraley as Treasurer of the Institute, to take effect upon the installation of his successor after the annual election in January, 1883.

Mr. Wm. V. McKean, thereupon, after alluding in very complimentary terms to the long and faithful service of Mr. Fraley, offered the following resolutions, which were seconded by Mr. Hector Orr, with appropriate remarks, viz.:

Resolved by the Franklin Institute, December 20, 1882:

1. That the Institute hears with very great regret the resignation by Frederick Fraley of the office of Treasurer, to which he was first elected in 1830, and the duties of which he has discharged with marked ability, zeal and fidelity for thirty-six of the intervening fifty-two years.

2. That the Institute accepts the resignation of Mr. Fraley, and tenders to him this expression of the gratitude and thanks of its memmers for his labors of love of so many years, and their best wishes for his enjoyment of many years to come.

3. That the Board of Managers be requested to have these resolutions engrossed and presented to Mr. Fraley.

The above resolutions were unanimously adopted.

The Actuary also read a letter from Mr. W. F. Dubois, resigning his membership in the Board of Managers. An election was thereupon held to fill the vacancy, which resulted in the choice of Dr. Isaac Norris.

Upon the call for reports from Standing Committees, the Secretary reported from the Committee on Science and the Arts, that the Committee had recommended the award of a Certificate of Merit to Alfred Wilkinson for his Metallic Piston Rod Packing, and to Wm. R.

Fowler for his Cloth Cutting Machine. The award was, in both cases, approved.

Mr. Wm. V. McKean, from the Committee on Sections, made the following report:

Hall of the Franklin Institute, December 18, 1882.

A meeting of the Committee on "Sections" was held this date at the Hall. Present: Messrs. Marks, Thorne, and McKean.

After discussion, it was resolved to recommend that "Sections" be instituted as follows:

(1) Sanitary Engineering—with special reference to household plumbing and drainage, and connecting private and public sewerage.

(2) Ventilation—with the view of correcting wastage of fuel for heating purposes; the withdrawing of damaging currents of cold air; and the injurious effects produced in some instances in the sick chamber, and in hospital wards, by the upward draught of noxious matter.

(3) Road Making—with reference to the paving of cities, and especially for suggestions of improvement in the paving of Philadelphia.

W. V. McKean,
Chairman Committee on Sections.

The following nominations were made for officers, to be chosen at the annual election in January: President, Wm. P. Tatham; Vice President, Frederick Graff; Secretary, Dr. Wm. H. Wahl; Treasurer, Samuel Sartain; Managers, E. J. Houston, William H. Thorne, Persifor Frazer, Enoch Lewis, William Helme, C. H. Banes, John J. Weaver, Frederick Fraley, James Dougherty, G. Morgan Eldridge; Auditor, Wm. A. Cheyney.

The Secretary's report embraced the following noteworthy novelties:

Sleeman's Gas Governor, exhibited by the Philadelphia Gas Saving Company. The device is a meter governor, as distinguished from a burner governor, and is intended to automatically regulate the pressure of gas so as to prevent blowing and waste of gas, while at the same time insuring a more steady and uniform flame. The governor, for actual use, is made of brass, with a balance valve and float sealed in glycerine. In addition to the brass governor, one made of glass was exhibited that its operations might be seen. A gauge was also provided whereby it was shown that the pressure was maintained as nearly as possible constant, no matter whether one or a dozen burners were in use.

The Chamberlain Automatic Pressureo-gverning Gas Burner was also shown. It has an arrangement of a floating valve in the burner, whereby the pressure at the tip of the burner is kept constant, notwithstanding variations of pressure in the main.

Samples of Loiseau's patent fuel were exhibited, and the Secretary stated that the fuel is now being successfully manufactured at the company's works at Port Richmond, and that the demand exceeds the capacity of the works. It is made into egg-shaped lumps, anthracite coal dust being mixed with a small quantity of bituminous coal dust and coal tar pitch.

Wm. T. McRae's friction clutch, the Monitor Heat and Gas Regulator, samples of silk from Nellie Lincoln Rossiter, and John G. Avery's Multiple Wire Belting for sewing machines and other machinery, Charles Kennedy's Belt Fastener, etc., were also exhibited.

Mr. Hugo Bilgram showed two-gear wheels, made by a machine, the principles of which he described before the Institute about a year ago, when he exhibited an odontograph for laying out gear wheels. He stated at the time that it could be easily adapted to cut the teeth automatically, and he has since constructed the machine, which he states produces theoretically perfect gear wheels that gear together as perfectly as the limitations upon the absolute accuracy of machinery will permit.

Blodgett Bros. & Co. exhibited an electric signal clock, now in use in the stations of the New York and New England, and Boston and Albany railroads for signaling the time of the departure of trains. An upright cylinder of brass contains 1440 holes arranged on 24 spirals (one for each hour). Brass pegs are put into the holes representing the minute when a gong is to be sounded. Through these pegs connection is made with an electrical circuit, which is thus completed and brings into play an electro-magnet, whereby the gong is sounded. Arrangement is made for a change of time on Sunday, which is worked automatically. The apparatus was shown at work, and gave a satisfactory performance. Two forms of the same device were shown. They were connected with Mr. Spellier's standard clock, used at the Institute for operating his Time Telegraph.

Chambers' Bros. brick machine, as recently improved, was exhibited, making bricks one-fourth the size of a Philadelphia brick. It has a sanding box, recently added, which sands the bar of clay as it issues from the mould, before it is cut to brick lengths.

Mr. Chambers gave an interesting description of the practical difficulties overcome in adapting the machinery to work all kinds of clay, just as it comes from the bank. The machinery is entirely automatic. Clay is fed into a hopper, and without further handling comes out on an endless traveling belt a perfectly moulded and sanded brick, ready to be dried and baked.

Mr. Chambers also exkibited samples of brick of various forms, and some of them made with large admixture of iron ore, and displayed on the screen diagrams of machines similar to those for brick making, intended to be employed in moulding artificial fuel in any desired form. He also stated that one of the machines was employed with excellent results at Lebanon in compressing iron ore that in its natural state would clog the furnaces, but can be used to good advantage if first moulded into bricks of convenient form.

The meeting was thereupon adjourned.

William H. Wahl, *Secretary.*

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AN ACCOUNT OF CERTAIN TESTS OF THE TRANSVERSE STRENGTH AND STIFFNESS OF LARGE SPRUCE BEAMS.

[An address delivered before the American Society of Mechanical Engineers on November 3, 1882.]

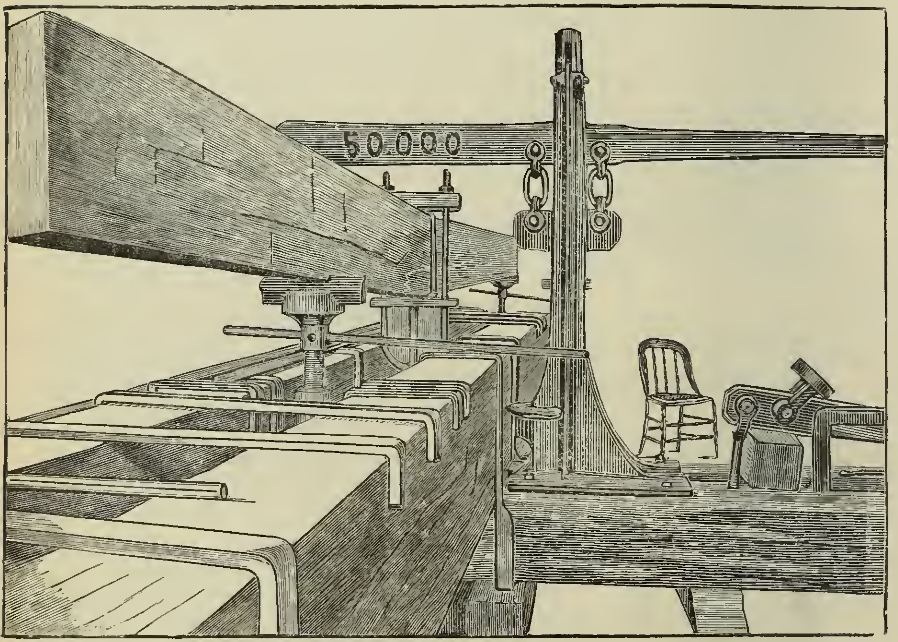
By GAETANO LANZA.

Professor of Applied Mechanics, Massachusetts Institute of Technology.

MR. PRESIDENT AND GENTLEMEN:—I beg leave to call your attention to the results of certain tests of the transverse strength and stiffness of full size spruce beams, carried on by members of my classes in my laboratory at the Massachusetts Institute of Technology. The machine with which they were made is a 50,000 pounds machine, and is capable of testing beams twenty-five feet long and under, as well as many of the framing joints used in practice.

It consists, as shown in the cut, of a compound lever, hung in a cast iron frame, to which is connected, by means of a steel rod and turn buckle, one end of a lever, of equal arms, placed below, this lever having a 12-inch leverage, and being connected at its other end by means of a chain, with the yoke shown in the cut. Two hard pine beams, each 20 inches deep, 10 inches wide and 26 feet long, are laid across the timbers of the machine in such a way that the chain

already referred to is midway between them. Two common jack screws, each in a pair of wrought iron stirrups, are placed at a distance apart depending upon the span of the beam to be tested, the latter being placed, as shown in the cut,* upon the jack screws, and under the yoke. The jack screws are then screwed up, and the beam to be tested is thus raised at its two ends, and hence loaded at the point where the yoke is attached.



It was in operation about two months, last session, and has been in operation about one month, this present session. During that time we have tested about thirty specimens for breaking strength, and about fifteen for deflection. The breaking has been effected as rapidly as could be done, consistently with the determination of the deflections, and the deflections under various loads were measured within a very short time after the application of the loads. In short, no experiments have thus far been carried on to determine the effect of time upon these quantities, though some will be made very soon. It was also deemed best to keep to one kind of timber, until we should have a sufficient number of tests to warrant us in drawing a conclusion as to

* [We are indebted to the *Boston Journal of Commerce* for the use of this cut.]

No. of test.	Width and depth in inches.	Distance between supports. Ft.	In.	Manner of fixing the ends and loading.	Breaking weight in pounds.	Modulus of rupture in lbs. per sq. in.	Modulus of elasticity in lbs. per square inch.	Remarks.
1	2 x 12	6	8	Framed at ends..........................	6,501			
2	4 x 12	6	8	Header..	10,338			
3	2 x 12	15		Load at middle..............................	5,891	5,526	1,237,215	
4	2 x 9	6	7·5	" "	7,322	5,389	1,067,893	
5	2 x 12	15		" "	5,586	5,237		
5(*a*)	2 x 12	7		" "	8,982			
6	2·75 x 9	6	8	" "	7,586	4,082	938,453	
7	3 x 9	4		" "	11,086	3,285		
8	3 x 9	10		" "	6,086	4,508		
9	3 x 9	15		" "	5,086	5,651		
10	3⅞ x 12	20		" "	6,586	4,253		
11	2·5 x 13·5	10		" "	9,585	3,787		
12	3·75 x 12	16		Load 4·5 ft. from one support....	7,585	3,271		
13	3·75 x 12	16		Ditto, mortised..............................	9,085			
14	7 x 2	7		Load at middle..............................	1,911	8,748	....	Selected stock.
15	1·75 x 6·75	7		" "	4,785	7,562	....	
16	3 x 9	6	8	" "	9,985	4,931		
17	3 x 9	6	8	Load at 4 points, 16 ins. apart....	16,744	4,961		
18	3·9 x 12	16		Load 4·5 ft. from one support....	12,585	5,218		
19	2 x 12	14		Load at middle..............................	4,401	3,854	1,482,645	
20	2 x 12	14		" "	5,108	4,469	1,588,518	
21	3 15/16 x 12	14		" "	8,627	3,834	1,187,073	
22	3⅞ x 12	14		" "	12,515	5,666	1,332,715	
23	3⅞ x 12¼	14		" "	6,917	2,995	897,961	
24	3 x 11⅞	14		" "	8,927	5,112	1,572,470	
25	2 x 9¾	14		" "	3,198	4,239	1,460,620	
26	2¾ x 12	14		" "	6,819	4,339	1,396,667	
27	1 15/16 x 10	14		" "	4,306	5,601	1,355,860	
28	4⅛ x 12	18		" "	8,829	4,816	1,397,136	
29	4 x 12⅛	18		" "	8,321	4,586	1,259,221	
31	3⅛ x 12	18		" "	7,721	5,559	1,231,498	
						25)115,499	15)19,405,978	
					Av. mod. of rupture =	4,620	Av. mod. of elast. = 1,293,732	

the average value of the modulus of rupture, and of the modulus of elasticity of that kind of wood; and spruce was selected, as a wood that is very much used in building. Experiments are now in progress in my laboratory to determine the same quantities for yellow pine.

The results that were obtained last session are shown above the double line in the accompanying table, and those obtained this present session, below.

At the beginning of this session these tests were continued, with the following objects in view:

1. Inasmuch as the lumber had, last session, been selected either by a carpenter, without reference to testing, or had been simply ordered at the yard, directions being given to the dealer to send merchantable stock, it seemed best that I should go to the yards myself and select from the piles some of the best and some of the average of what was on sale as merchantable stock, and thus that we should be able to speak with certainty about the values of the modulus of rupture and modulus of elasticity of such lumber.

2. Inasmuch as last year we had had only three determinations of the modulus of elasticity, it was desirable to obtain more values, and thus to be able to determine an average value.

3. It was desirable to see how far, in the light of what had already been done, we should be able to judge of the modulus of rupture by simply inspecting a piece of timber, and to endeavor also to train the students, to some extent, to have this ability.

That the values of the modulus of rupture which we have obtained should differ very considerably from those given in our text-books and engineers' handbooks, and deduced from tests of small pieces, I need not tell a company of engineers; but, as you may not carry in your minds the precise figures given by different authorities for the modulus of rupture of spruce, I will place them here:

Hatfield gives as mean value,	. .	9,900	lbs. per. sq. in.
Rankine, "	" .	11,100	"
Laslett, "	" . .	9,045	"
Trautwine, "	" .	8,100	"
Rodman, "	" . .	6,168	"

Trautwine advises for use to deduct one-third in the case of knotty and poor timber.

As a result of the tests thus far made in my laboratory, it seems to me safe to say, that if our Boston lumber yards are to be taken as a fair sample of the lumber yards in the case of spruce, that if such lumber is ordered from a dealer of good repute, no selection being made except to discard such pieces as might be classed as culled timber, *i. e.*, that which is rotten or has holes in it, that 3000 pounds per square inch is all that could with any safety be used for modulus of rupture, and even this might err in some cases, in being too large. 2. That if the lumber is carefully selected at any one lumber yard, so as to take only the best of their stock, it would not be safe to use for modulus of rupture a number greater than 4000, and if we required a lot of spruce lumber which should have a modulus of rupture of 5000 it would be necessary to select a very few pieces from each lumber yard in the city.

Next, as to the modulus of elasticity: until the beginning of this session we had made only three experiments on this subject, and these gave as an average 1,081,187; those made this autumn have contributed to raise this value somewhat, as will be seen from the table, where we obtain an average of 1,293,732.

Of course it is naturally to be expected that time tests will give much smaller values for both modulus of rupture and modulus of elasticity.

As to the variations of the values shown in the table, they are considerable, and depend upon the quality of the lumber, *i. e.*, upon the number and location of the knots, the shakes and cracks that are so commonly found at the heart of timber, also upon the degree of seasoning, although it is my opinion that the increase of strength due to this latter item has often been over-estimated. Knots near the middle of the span act very prejudicially, whether they are at the top or at the bottom, and by saying near the middle of the span I mean to include a very considerable range. It is impossible, however, to describe the mode of judging correctly, from inspecting a stick, what will be its modulus of rupture, and this ability can only be acquired by practice, and this very practice is one of the benefits that it is hoped to enable the students to gain to a greater or less degree.

As to the relation between the modulus of rupture and the modulus of elasticity, whilst it is generally true that those pieces that have a high value of the one have a high value of the other, and *vice versa*, nevertheless, I have not been able thus far to form any definite idea of

the connection between them, at least such as to enable one to attempt to predict the modulus of elasticity from the appearance of the piece. Perhaps further experiments may satisfy this want, and as to the desirability of satisfying it no one can have any question, for the stiffness of beams is, or ought to be, as prominent a question to builders as their breaking strength.

We have already made three, and shall make quite a number of experiments on the strength of framing joints, such as headers, trimmers, etc., in regard to which we have thus far been entirely devoid of any experimental knowledge.

As to the method of fracture: while the most usual fractures in spruce beams have occurred either by tension or compression, or a combination of the two; nevertheless in some cases the beams have been split from the middle to one end, along or near the neutral axis; and while the experiments where this kind of fracture has occurred are not sufficient in number to warrant definite conclusions as yet, nevertheless it is an element that is forcing itself very strongly upon our attention as one that must be taken into account in practice.

A noticeable instance of this kind is to be found in the case of beam No. 22, another in beam No. 24, and a third in beam No. 31, which gave way in that manner.

At the meeting a number of photographs of the fractures obtained were exhibited and commented upon.

Table of Tests.

The following are the records of the tests made during the first month of the present session by students in the Department of Applied Mechanics of the Massachusetts Institute of Technology. In these tables, as far as the deflections are concerned, the first load is assumed as the start point, the deflection under that load being counted zero.

The deflections are recorded to the 10,000th of an inch, as the measurements were made with a micrometer screw that could be read to that degree of accuracy, and hence it was thought best to give the results as they were obtained, although it is not claimed that change of temperature or other disturbing causes, which would be inappreciable as far as any practical result is concerned, may not cause so great a variation as to render it unnecessary to read to such a degree of accuracy.

The spruce, with the exception of Nos. 22 and 23, was cut in the spring of 1882, and brought from Bangor, Me. Nos. 22 and 23 were

cut in 1881. The students making the tests, hand in the reports of the same, and make the necessary computations of modulus of rupture, modulus of elasticity, etc. The values given in the tables have been re-computed by my assistant, Mr. Edward F. Ely.

The number given as the "Max. intensity of shear at neutral axis" is that which would be obtained by computing it from the breaking load in accordance with the ordinary theory of beams.

No. 19.—Spruce Joist, 2 in. by 12 in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
686	·0473	·0473	Rested over night.
510	....	....	Load on next morning.
485	·0000	....	Began new set of readings.
686	·0343	·0343	
887	·0825	·0482	
1,088	·1284	·0459	
1,088	·1309	....	After 1 hour.
1,289	·1764	·0455	
3,600	....	....	Cracks opened near centre above neutral axis.
4,103	....	....	Bulging on east side at top. At centre top slewed to west.
4,404	....	....	Breaking load.

Fracture occurred within an hour after application of breaking load.

Line of fracture followed the knots.

Modulus of rupture = 3,854 lbs. per square inch.

Mean deflection for 201 lbs. = ·0465.

Modulus of elasticity = 1,482,645 lbs. per square inch.

Maximum intensity of shear at neutral axis = 138 lbs. per square inch.

No. 20.—SPRUCE JOIST, 2 in. by 12 in. Span 14 feet. Loaded at centre. Not many knots.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
686	·0431	·0431	
887	·0885	·0454	
1,088	·1303	·0418	
5,813	....	....	Twisted badly in spite of bracing, and load fell off rapidly, it being impossible to keep this load on.
5,108	....	....	Breaking load.

Modulus of rupture = 4,469 lbs. per square inch.

Mean deflection for 201 lbs. = ·0434.

Modulus of elasticity = 1,588,548 lbs. per square inch.

Maximum intensity of shear at neutral axis = 160 lbs. per square inch.

No. 21.—SPRUCE JOIST, $3\frac{15}{16}$ in. by 12 in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
686	·0000		
1,088	·0546	·0546	
1,490	·1033	·0487	
1,892	·1654	·0621	
2,294	·2192	·0538	
2,696	·2858	·0666	
3,098	·3397	·0539	
3,500	·4030	·0633	
3,902	·4644	·0614	
4,304	·5256	·0612	
4,706	·5898	·0642	Left over night.
4,203	.5815	....	Next morning.
4,706	·6529	....	Load increased to 4,706 again.
4,401	....	....	Next day.
5,610	....	....	Braced the stick.
8,627	....	....	Breaking load after carrying 15 minutes.

Modulus of rupture = 3,834 lbs. per square inch.

Mean deflection for 402 lbs. = ·0590.

Modulus of elasticity = 1,187,073 lbs. per square inch.

Maximum intensity of shear at neutral axis = 137 lbs. per square inch.

No. 22.—Spruce Joist, $3\frac{5}{8}$ in. by 12 in. Span 14 feet. Loaded at centre. Lower part of tree. Very free from knots. Had been seasoning on the wharf about one year.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0534	·0534	
1,289	·1052	·0518	
1,691	·1583	·0531	
2,495	·2665	·1082	
3,299	·3748	·1083	
4,103	·4810	·1062	
4,907	....	....	Left over night.
4,203	....	....	Next morning.
12,515	....	....	Breaking load. Beam broke by tension and afterwards by shearing along the neutral axis. Shear extended from centre to one end, and pieces slid by one another about $\frac{7}{16}$ inches.

Modulus of rupture = 5,666 lbs. per square inch.

Mean deflection for 402 lbs. = ·0534.

Modulus of elasticity = 1,332,715 lbs. per square inch.

Maximum intensity of shear at neutral axis = 202 lbs. per square inch.

No. 23. —Spruce Joist, $3\frac{7}{8}$ in. by $12\frac{1}{4}$ in. Span 14 feet. Loaded at centre. Upper part of same tree as No. 22. Very knotty. Had been seasoning on the wharf about one year.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0819	·0819	
1,289	·1457	·0638	
1,691	·2204	·0747	Left over night.
1,425	....	....	Next morning.
1,691	·2569	....	Raised load again.
2,093	·3269	·0700	
2,495	·4017	·0748	
2,897	·4828	·0811	
3,299	·5536	·0708	
4,103	·7073	·1537	
4,907	....	....	Left on for half an hour, during which time load fell off to 4,203; beam splitting and cracking at a large knot on lower edge near centre of span.
6,917	....	....	Breaking load (knot causing break about 15 inches from centre).

Modulus of rupture = 2,995 lbs. per square inch.

Mean deflection for 402 lbs. = ·0745.

Modulus of elasticity = 897,961 lbs. per square inch.

Maximum intensity of shear at neutral axis = 108 lbs. per square inch.

No. 24.—Spruce Joist, width $3\frac{1}{16}$ in. at bottom, $2\frac{7}{8}$ in. at top, depth $11\frac{7}{8}$ in. Span 14 feet. Loaded at centre. Not many knots.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0603	·0603	
1,289	·1247	·0644	
1,691	·1835	·0588	
2,093	·2485	·0650	Left 15 hours, when load had fallen to 1,766 lbs.
2,093	·2742		
2,495	·3285	·0543	
2,897	·3870	·0585	
3,299	·4521	·0651	
3,701	·5189	·0668	
4,103	·5746	·0557	
8,927	....	....	Breaking load. Broke by shearing along neutral axis. Split opening about 1½ inches.

Modulus of rupture = 5,442 lbs. per square inch.

Mean deflection for 402 lbs. = ·0610.

Modulus of elasticity = 1,572,470 lbs. per square inch.

Maximum intensity of shear at neutral axis = 190 lbs. per square inch.

No. 25.—Spruce Joist, 2 in. by $9\frac{3}{4}$ in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1625	·1625	
1,289	·3342	·1717	
1,691	·5280	·1938	
3,198	....	....	Breaking load, by compression at top and tension at bottom.

Modulus of rupture = 4,239 lbs. per square inch.

Mean deflection for 402 lbs. = ·1760.

Modulus of elasticity = 1,460,620 lbs. per square inch.

Maximum intensity of shear at neutral axis = 123 lbs. per square inch.

No. 26.—Spruce Joist, $2\frac{3}{4}$ in. by 12 in. Span 14 feet. Loaded at centre. Ordinary stock.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·0534	·0534	
1,691	·2050	·1516	
2,495	·3610	·1560	
3,299	·5025	·1415	
5,610	....	....	Cracked somewhat.
5,713	....	....	Cross-grained fibre at bottom tore apart.
5,914	....	....	A sharp crack was heard and a long split appeared.
6,819	....	....	Breaking load.

Modulus of rupture = 4,339.

Mean deflection for 402 lbs. = ·0718.

Modulus of elasticity = 1,396,667 lbs. per square inch.

Maximum intensity of shear at neutral axis = 155 lbs. per square inch.

No. 27.—Spruce Joist, $1\frac{15}{16}$ in. by 10 in. Span 14 feet. Loaded at centre. Not many knots.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1724	·1724	
1,289	·3272	·1548	Beam tipped and braces were put in at ends beyond the straight edges.
1,691	·5141	·2169	Wedge was used on west side to keep straight edge close to the beam.
4,306	....	....	Breaking load.

Modulus of rupture = 5,601 lbs. per square inch.

Mean deflection for 402 lbs. = ·1814.

Modulus of elasticity = 1,355,860 lbs. per square inch.

Maximum intensity of shear at neutral axis = 167 lbs. per square inch.

No. 28.—Spruce Joist, width $4\frac{1}{4}$ in. at bottom, 4 in. at top, depth 12 in. Span 18 feet. Loaded at centre.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1049	·1049	
1,691	·2999	·1950	
2,495	·5030	·2031	
3,299	·7033	·2003	
3,701	·8136	·1103	
4,103			
8,829	....	....	Breaking load.

Modulus of rupture = 4,816 lbs. per square inch.

Mean deflection for 402 lbs. = ·1017.

Modulus of elasticity = 1,397,136 lbs. per square inch.

Maximum intensity of shear at neutral axis = 134 lbs. per square inch.

No. 29.—Spruce Joist, 4 in. by $12\frac{1}{8}$ in. Span 18 feet. Loaded at centre.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1048	·1048	
1,289	·2169	·1121	
1,691	·3267	·1098	
2,093	·4421	·1157	
2,495	·5488	·1064	
2,696	·6227	·0739	
2,897	·6768	·0541	
6,917	....	....	Slight cracks heard.
8,324	....	....	Breaking load.

Modulus of rupture = 4,586 lbs. per square inch.

Mean deflection for 402 lbs. = ·1128.

Modulus of elasticity = 1,259,224 lbs. per square inch.

Maximum intensity of shear at neutral axis = 129 lbs. per square inch.

No. 31.—Spruce Joist, $3\frac{1}{8}$ in. by 12 in. Span 18 feet. Loaded at centre.

Tested by Messrs. Davis and Morse.

Load in lbs.	Deflection in inches.	Differences.	
485	·0000		
887	·1486	·1486	
1,289	·3030	·1544	
1,691	·4514	·1484	
2,093	·6129	·1615	
2,495	·7615	·1486	
3,701	....	....	Cracking commenced.
7,721	....	....	Breaking load. Broke suddenly by compression of top fibres and shearing along the neutral axis. Split showed several small pin knots, running vertically in the beam, and apparently pinning the sides of the fracture together.

Modulus of rupture = 5,559 lbs. per square inch.

Mean deflection for 402 lbs. = ·1523.

Modulus of elasticity = 1,231,498 lbs. per square inch.

Maximum intensity of shear at neutral axis = 154 lbs. per square inch.

Fracture of Steel.—Ruptures often occur in steel, which are very difficult to explain. They are generally attributed to inequality in cooling or to imperfect annealing, but some experiments, which have been reported to the institution of naval architects, seem to show that the fractures are always attributable to a defect in the quality of the steel before rolling, and not to the inequality of the strains to which it is finally subject. When a piece of sound steel plate was heated to redness, and then cooled unequally by scattering water on various parts of the heated surface, it was hammered in various ways and submitted to a series of experiments of the most trying character, without giving any indication of fracture.—*Chron. Industr.*, No. 39. C.

THE ABSTRACTION OF HEAT BY MECHANICAL ENERGY.*

By John Rowbotham.

[A paper read at the stated meeting of the Franklin Institute, November 15, 1882.]

It is now a well-established fact that "Heat is Energy," and that one British thermal unit corresponds to 772 foot pounds of mechanical energy; but in the sequel we will endeavor to show that mechanical energy is also extensively used for the purpose of producing cold, or *abstracting* heat.

We do not propose going deeply into the theory of this process, but will merely confine ourselves to certain practical points, and state principally what has come under our immediate and personal observation.

In this particular latitude where crops of *natural ice* can, during the winter months, be gathered, the production of cold by its use is comparatively easy, although even here it is not always inexpensive; nor is the atmosphere thus obtained always the most desirable, viz.: where a *dry* atmosphere is required.

For certain purposes, however, the production of cold by means of ice has the advantage of simplicity; for instance, the confectioner will fill a metallic vessel, or can, with cream, and by surrounding it with broken ice, freely sprinkled with common salt, will soon freeze the cream; the plumber in repairing a water-pipe, to make a joint or new connection, to avoid digging up the street to reach the "ferrule" connection at the "main," or stopping off of the water in the main pipe, will first get at the point where the work is to be done, stopping the flow of water through the pipe by closing all the outlets, then by covering it with ice and salt, on the pressure side of the point to be worked at, in a very short time finds the water sufficiently frozen to enable him to complete his work.

In the cases cited the object sought was to get rid of a certain amount of heat; but paradoxical as it may seem to many, the railway-man will use the same process—mixing salt and snow to prevent ice from forming and remaining upon the tracks, curves, and switches. Com-

* It may be unnecessary to state that wherever in this paper the term "Production of Cold" is used, a corresponding "Abstraction of Heat" is meant, since "cold" though a popular expression, is in reality the absence of heat. [The Author].

mon as these practices are, comparatively few who adopt them can clearly give the reasons for the effect produced.

The low temperature obtained in these cases is simply due to the capacity that certain substances have, when mixed together, of lowering the temperature of the melting point of the mixture. This is taken advantage of by the railway-man, who, by salting the snow, lowers the freezing temperature to about 0° Fahr. instead of 32°; but in melting, every pound of ice will take up as much heat as would raise a pound of water through 142°, and this serves the object of the confectioner and plumber—the heat required to melt the ice and salt being supplied in the one case by the cream, and in the other by the water in the pipe.

We know that in the greater portion of the globe, ice is not produced naturally, and that the cost of transportation makes it too expensive for general use, hence it is a luxury only to be indulged in by the wealthy; but inasmuch as the habits of all the people of the earth appear to be undergoing a radical change, through the rapid advancement of civilization, we predict that the time is not far distant when *ice* and *cold* will be considered as much of a necessity as *heat*, and this demand, in certain localities, must be supplied by artificial means.

The process of producing cold artificially, depends principally on the property of gases and vapors to become heated by compression, and cooled by expansion, and although this property was previously known, no definite relation between temperature and pressure, on which to base a calculation, had been established until Gay Lussac, at the beginning of the present century, found by a series of careful experiments, a mathematical expression for it; the truth of his conclusions has since been fully verified, by the experiments of Regnault and other scientists.

Lately a number of practical machines have been constructed in England based on this property of gases, and using atmospheric air as the means to produce cold, of which the "Giffard," the "Piggot," and the "Bell-Coleman" machines may be cited as illustrations; the last named being the pioneer in a new branch of trade, that of carrying fresh meat from New Zealand to London by sailing-ship. One hundred and seventy-five tons of meat were taken on board and frozen at the rate of ten tons per day, being at the time stowed away in the hold of the ship; the temperature below deck was always maintained below the freezing point whilst loading, and also during a voyage of ninety-eight days.

In these machines the air is compressed, by powerful steam engines, to a pressure of about two and a half atmospheres, its temperature rising to about 218° Fahr., depending on the temperature of the air to be compressed; it then passes into a "condenser" or vessel, where cold water is circulating, and by which the heat of the air is removed. The pressure of the air after cooling will still be considerable, and it is made to perform work in an expansion cylinder, the pressure falling to that of the surrounding atmosphere, and the temperature to about 35° below 0°. It is now expelled, and will be capable of taking up an amount of heat, equal to that removed from it by the circulating water, this heat being supplied by the objects to be frozen. These machines, though simple and capable of producing a low temperature, are not considered very satisfactory; this is due principally to the low specific heat of air, 50 cubic feet being required to cool one pound of water (a pint), degree for degree, which may be stated, the same quantity of heat will raise 50 cubic feet of air through as many degrees as it will 27 cubic inches of water. This necessitates very cumbrous machinery, and a corresponding waste of energy to accomplish a given result.

Their failure in practice is also due, in a great measure, to mechanical difficulties not easily overcome; they require large and easily worked, yet thoroughly air-tight, pistons and valves—conditions not readily attainable; and, moreover, the cold produced in the expansion cylinder congeals the moisture of the air, which, besides obstructing the passages, is equivalent to so much waste of energy, since the cold here produced cannot generally be utilized.

In this country, and in some of the countries of Europe, air machines have not been used to any great extent. Machines using some chemical, or liquid whose boiling point, at the pressure of the atmosphere, lies generally below the average atmospheric temperature, having been found more effective. In fact, in the first machines by which ice was successfully made to any extent, ether was the agent by which the heat was abstracted.

In 1850 to 1853, Professor A. C. Twining, of Hudson, Ohio, succeeded in practically demonstrating the feasibility of this process, and in 1858 an inventor named Harrison, of Geelong, Australia, made similar experiments in London with the same substance, he having produced from 5000 to 6000 pounds of ice per day with an engine of ten horse power.

In all machines using a chemical, the heat-carrying agent is maintained constantly in circuit, this agent not being expelled at a certain point as in air machines. The process of producing the cold is nearly the same in these as in the air machines, the vapor being compressed by the pumps into a condenser, and the heat due to the compression removed, liquefaction takes place; the liquid being then led into a system of pipes which are connected with the pump, and where the pressure is maintained below the boiling point of the liquid at the required temperature. The liquid will therefore boil or evaporate, abstracting at the same time from the surroundings, an amount of heat equal to that made latent by the evaporation, and the vapor formed will be taken up by the pump and again compressed, thus completing the circuit.

In all cases it is necessary that the whole apparatus shall be so tight as to exclude both air and water, as well as to prevent any leakage of the chemical; this, though not by any means an easy matter to accomplish, is of the utmost importance, since a leak *inward*, by admitting moist air or water, will, with some substances, ruin the entire apparatus; and a leak *outward*, not only wastes the chemical, but has in some cases been the cause of serious disasters to both life and property.

The principal points in favor of these machines is their small size compared with air machines. In a great part of the circuit the substance is in the liquid state, requiring tubes and vessels of very small dimensions.

In the air machines, the capacity of a certain volume of air for abstracting heat, depends entirely upon its *specific* heat; whilst in machines using liquefiable vapor the *latent* heat of the vapor is far more potent in this respect than the specific heat. And since the latent heat of most of the substances used is quite high, its utilization becomes of great advantage.

The substances generally used for the abstraction of heat are ammonia, sulphur di-oxide, methylic ether, chymogene, and others. Each of these substances has its advocates, and the superiority of one over another may depend much upon circumstances and the degree of cold to be produced. Yet, where the saving of space is important, many points are evidently in favor of ammonia.

There are two classes of ammonia machines in use, one using aqua ammonia, and the other the liquefied vapor, or anhydrous ammonia. In the former of these "absorption" machines, as they are called, the cold may be said to be produced directly by heat, without its previous

conversion into mechanical energy, the ability which water has of absorbing many times its volume of ammoniacal vapor being utilized to dispense with a large part of the machinery. So far, however, these machines have not proved as effective in the production of cold as those using mechanical energy.

To illustrate the advantage of anhydrous ammonia in point of space, a comparison of the relative latent heat of the substances named will be made, viz.:

Relative latent heat per equal weight,		
	Ammonia,	90
	Sulphur Di-oxide,	26
	Methylic Ether,	30
	Chymogene,	17

and since the weight required to abstract a certain quantity of heat will be inversely as the latent heat of the substance, we see that the evaporation of *one* pound of ammonia will abstract as much heat as *three and a half* pounds of sulphur di-oxide, *three* pounds of ether, and *five and a quarter* pounds of chymogene.

The only reasonable objection that has been urged against the use of ammonia is the low temperature of its boiling point under atmospheric pressure, or inversely, the high pressure required to liquefy it at ordinary temperatures; this pressure need not, however, exceed 14 atmospheres absolute, or 206 pounds per square inch, which can be easily managed with proper apparatus.

But the boiling point of ammonia being low, becomes of great advantage where low temperatures are required; the pressure of its vapor being quite high, at a temperature where that of other substances is almost a vacuum, and this, taken in connection with the high latent heat of its vapor, makes the advantage gained by its use very apparent.

Pressure per square inch at 0° Fahr.,			
	Ammonia,	30	lbs. absolute.
	Sulphur Di-oxide,	10	"
	Methylic Ether,	20	"
	Chymogene,	2	"

Assuming the volumes of the vapors to be inversely as the pressures, there would correspond to *one* volume of ammonia *three* of sulphur di-oxide, *one and a half* of methylic ether, and *fifteen* of chymogene, and combining this with the relation of the latent heat already given, it will be seen that where the formation of *one* volume of ammoniacal

vapor abstracts a given number of heat units, *ten and a half* volumes of sulphur di-oxide, *four and a half* of methylic ether, and *seventy-nine* of chymogene would be required to produce the same result. By these comparisons it will readily be seen that the whole apparatus and especially those parts through which the substance passes as vapor, will be of very small size, where ammonia is used, in comparison to that required when using any other substance; and this, which we have endeavored to explain at some length, we consider the most valuable point in its favor.

It is also non-poisonous as well as non-explosive, neither does it support combustion, that is to say, a burning taper introduced into the vapor is immediately extinguished—admirable points which give it precedence over substances like *ether* and *chymogene*, which are both liable to the objectionable features named. It is not known to produce any injurious effects upon either iron or steel, acting instead, when in a liquid state, as a good lubricant on those metals; mixed with water or moist air, it does not produce any deleterious action upon the apparatus, as is the case with sulphur di-oxide, where the admission of moisture is liable to cause a chemical change of the substance into sulphuric acid, or oil of vitriol, the injurious qualities of which are well known.

Ammonia being a strong alkali, non-saponifiable oils must be used where lubrication is required; these can be used indefinitely, as it is not known to have any action on them whatever.

Having so far endeavored to show the superiority of ammonia as a heat-carrying agent, we shall now give an outline of the apparatus required to produce a definite result.

Let it be required to abstract heat equivalent to the freezing of *ten tons of ice* in twenty hours, or a half a ton per hour, the water being at a temperature of 72° Fahr., the number of heat units to be abstracted per hour in reducing it to 32° and freezing it, would be 203,840, equal to 3397 heat units per minute. Supposing the temperature of the liquified ammonia, when in a condition to abstract heat from the water, to be at 0° Fahr., or 32° below the freezing point, one cubic foot of it, at that temperature, would require for its evaporation 36,295 heat units; but as the liquid when leaving the condenser is necessarily at a higher temperature, say 100°, a portion of it will be evaporated at the expense of the sensible heat, and subtracting this, it will be found that 30,762 heat units must be supplied by the water

for every cubic foot of ammonia evaporated. To abstract 3397 heat units would therefore require the evaporation of 191 cubic inches of liquid ammonia, corresponding to 95,616 cubic inches of vapor, which must be removed by the pump per minute.

Supposing the pump to make one hundred revolutions, if double-acting it would only need to have a capacity of 478 cubic inches, say 8 inches diameter by 10 inches stroke. Verifying what has been previously said about the small size of the apparatus.

The *initial* pressure corresponding to 0° Fahr. is about 30 pounds absolute, and the *final*, corresponding to 100° Fahr., about 200 pounds absolute, giving a ratio of compression of $6\frac{2}{3}$, and a mean effective pressure of 57 pounds per square inch, which for the above piston speed=167 feet per minute, and piston area=$50\frac{1}{4}$ square inches—would give a resistance of $14\frac{1}{2}$ horse power, which by adding 15 to 20 per cent. for prejudicial resistance will give the indicated horse power of the steam engine required to run it.

Additional power might be needed for the purpose of circulating water, etc., depending on the locality and the purpose for which the cold was intended; but in any case the available mechanical energy being known, the amount of cold it can produce may be easily calculated, and the results, as obtained in practice, sustain the truth, not only of the possibility, but also of the magnitude of the conversion of mechanical energy into cold.

Electric Illumination by Reflection.—D. V. Partz exhibited a plan of a new mode of electric lighting, at the French Electric Exposition. The light was placed in chambers underneath the street, and reflected through hollow cylinders, enamelled on the inside, so as to produce an inverted cone of rays, which strike a reflector placed at a height of 40 or 50 metres above the street. Among the advantages which are claimed by the inventor are: The employment of powerful electric foci, thus avoiding the loss which results from the division of the current; the equal diffusion of the light and the avoidance of the dazzling glare; the diminution of the loss of light which results from the employment of translucent globes; the readiness of access for regulation and surveillance; and the illumination of thick mists, which can be penetrated with difficulty by other methods.—*La Lumière Electrique,* Aug. 5, 1882.

ON THE APPLICATION OF THE PRINCIPLE OF VIRTUAL VELOCITIES TO THE DETERMINATION OF THE DEFLECTION AND STRESSES OF FRAMES.

By George F. Swain, S.B.

Instructor of Civil Engineering in the Massachusetts Institute of Technology, Boston, Mass.

I. Introduction.

The calculation of the deflection of a truss or girder is a subject which sometimes occupies the attention of the engineer, yet in regard to which some uncertainty seems to prevail. The deflection is of importance from several points of view, and it is sometimes considered an index of the strength of the structure; so that we sometimes find it specified that the deflection shall not exceed a certain quantity under a given load, to determine which systematic tests are made on the completion of the structure. There is no doubt, however, that the importance of the deflection as an index of strength has often been overestimated, and for the following reason: That the deflection consists of two parts, which must be carefully distinguished; first, that due to the changes of length of the bars composing the frame, on account of the stresses produced in them by the applied loads; and, second, that due to inaccuracies of workmanship,—to the fact that the parts do not exactly fit, that bolts and rivets are not of exactly the right size, etc.—so that the parts all come gradually to their permanent bearings, producing a certain deflection. The first sort of deflection may be called the *elastic*, the second the *non-elastic:* the first may be approximately calculated; the second cannot be: the first should be temporary, disappearing when the loads are removed; the second is permanent: the first is to a certain extent an index of the strength of the structure; the second is not. When a new bridge is loaded for the first time it deflects; but even if we measure the deflection, we have no means of knowing how much is elastic and how much non-elastic, consequently we cannot from this alone judge of the strength of the structure. If, as in the case of long spans and pin connections, we can be reasonably certain that the dead load alone is sufficient to bring all the parts to their permanent bearings, the measurement of the deflection would

have a certain value; or if a bridge has been in use long enough to render it certain that the maximum non-elastic deflection has been reached, the same is true; for in these cases the measured will be the elastic deflection. Yet, even here, a single measurement would have no value. By repeated applications of the load, however, we can observe whether the elastic deflection is gradually increasing, and so gain some insight into the condition of the structure; for if no increase be observed, we may know that no bar is strained beyond the elastic limit. Yet, even here, again, it would be just as easy to calculate the stresses in each bar, and so dispense with the measurement, except in cases where, for some reason, an exact calculation is impossible or uncertain. Again, in order to calculate the deflection of a frame, it is necessary to know the modulus of elasticity of each bar, regarding the value of which there is not often certainty; hence, if the calculated and observed deflections do not agree, no definite conclusions follow. It would no doubt be an advantage to confine the non-elastic deflection within certain limits, but how this can be done in any other way than by exercising care in the construction, it is difficult to see. It would seem, then, that the only value which a measurement of deflection has, is that by repeating the measurement we may judge whether any bar is strained beyond the elastic limit; and in view of our large factors of safety, which do not allow the elastic limit to be approached in good constructions, this value is not great.

But there is another point of view from which the deflection is of greater interest. There are some structures in which the stresses themselves depend on the deflections—structures which may be called "statically undetermined;" and although they do not occur often in the ordinary practice of the engineer, a study of their properties, and of the methods of calculating them, is of value and interest. The usual methods employed involve assumptions which are more or less removed from the truth, and the error committed in the calculation is of uncertain amount. Some of these structures, however, may be solved with exactness by means of a method which has been known for a number of years, and the application of which, though sometimes tedious, is not difficult. It is a method of successive approximation; and as its details may not be familiar to some readers of the JOURNAL, it may be of interest to give them in the following pages. The first application of the method is due, I believe, to Lamé; it was subsequently treated more fully by Maxwell and Jenkin in England; and

fully developed in recent years in Germany, in all its applications, by Mohr and Winkler. The object of this paper is to attempt to present an outline of the method and of its principal applications. Before doing so, however, it may not be out of place to recapitulate briefly a few facts regarding frames in general, and the conditions under which they are statically determined. We may do this the more briefly because of the appearance, since the present article was commenced, of an article by William Cain, C. E., in *Van Nostrand's Magazine* for October, in which some of these points are referred to.

A frame may be defined as an assemblage of bars united at their ends by hinges, and supported at one or more points. For the present let us consider the case of two points of support only. If such a frame is acted upon by forces applied at the joints, each rod will be subjected to longitudinal stress, and to find the stress in each piece is the problem to be solved. This problem presents two distinct parts: first, the determination of the outer forces, or reactions, by which the applied forces are held in equilibrium; and, second, the determination of the inner forces, or stresses in the bars; and in order to solve the second part of the problem, we must beforehand have solved the first. For the solution of either or both of these parts of the problem the laws of statics may not suffice, in which case the frame may be called statically undetermined as regards outer or inner forces, and in which, in order to effect a solution, it is necessary to resort to considerations based on the elasticity of the materials dealt with—generally to a determination of deflection.

Let us see now, first, under what conditions the *outer forces* may be determined on statical principles alone. The outer forces consist of

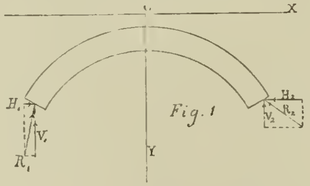


Fig. 1

the applied loads, which are known, and the reactions, which are unknown. Confining ourselves to the ordinary case of a frame of any shape, supported at two points, all of the bars lying in a plane, in which plane also the loads and reactions act, we resolve the two reactions R_1 and R_2 into their horizontal and vertical components, H_1 and H_2, and V_1 and V_2. Assume any system of rectangular axes Ox,

Oy, in the plane of the frame. In order to determine the reactions completely, eight unknown quantities must be found, namely, for each reaction its two components and the two co-ordinates of its point of application. To find these quantities eight equations are necessary. The surfaces of support being always given, afford two equations, between x_1, y_1, and x_2, y_2. For simplicity we may therefore consider that we have six unknown quantities, H_1, H_2, V_1, V_2, x_1, x_2, for which we require six equations. Statics furnishes us with but three—the equations of equilibrium of forces in a plane, expressing the fact that the loads are balanced by the reactions. Three additional equations or conditions are therefore necessary, if the frame is to be statically determined as regards the outer forces. The conditions usually given will be referred to again, in connection with the calculation of the outer forces in some of the most common cases. It is sufficient here to refer to the fact, that, of the three, one, and sometimes two or three, are derived from a consideration of the deflection of some point in the frame in some particular direction.

Passing now to the inner forces, let us see under what conditions the stresses in all the bars of the frame may be found from statical principles alone, the outer forces being supposed determined. At each joint of the frame the stresses in the bars meeting at that joint are the quantities to be determined; and the only statical conditions that we have, from which to determine them, are those expressing the fact that they are in equilibrium with the outer forces acting at the joint. The conditions of equilibrium for forces acting at a point are two in number; hence for each joint of the frame we can write two statical equations involving the unknown quantities; and if there are m joints in all, we have $2m$ statical equations. These $2m$ equations express the fact that each and every joint is in equilibrium, therefore that the entire frame is in equilibrium; hence they include the three conditions of equilibrium of the outward forces themselves, so that there remain $2m—3$ independent equations for the determination of the stresses in the bars, which we suppose n in number. To express this in another way, the $2m$ equations express the fact that the outer forces are balanced; we cannot, then, assume all of our outer forces *ad libitum*, because we must assume them so that they will satisfy the three conditions of equilibrium of forces in a plane; but we can assume all but three components, which we leave as unknown quantities, and we thus have $2m$ equations to determine the $n+3$ unknown quantities. It is clear, then,

that if the inner forces can be statically determined we must have the condition fulfilled:

$$2m=n+3, \tag{1}$$

and this equation must be fulfilled not only for the entire frame, but for any part which may be cut off from the rest, the stresses in the bars cut being considered outer forces. Equation (1), demonstrated above on mechanical principles, has been deduced by Maxwell and others geometrically, by considering the conditions under which any one bar may change its length without involving a change of length of the others.

It is not necessary to give many examples of the application of this condition. A rectangle with one diagonal, for instance, is statically determined, but if the second diagonal be added, it becomes statically undetermined. It may be remarked, however, that all bridge trusses which have more than one system of bracing are statically undetermined; and as such are the prevailing trusses used in this country, it may be well to show in a few words why this is so. We shall find, for instance, in Fig. 2, leaving out the two counter ties running from the point j,

$$2m=36\,;\ n+3=38:$$

and in Fig. 3,

$$2m=36\,;\ n+3=37.$$

In each of these cases, therefore, the number of unknown quantities

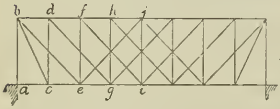


Fig. 2

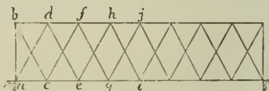


Fig 3

is greater than the number of equations. so that additional equations are needed in order to solve the problem.

If the number of equations should be greater than the number of unknown quantities, the system would be unstable, and would change its shape as the load changed; such is the case in flexible suspension bridges. It is easy to see why the two trusses considered above, are statically undetermined. They are generally solved by being resolved into two simple trusses; for example, in Fig. 2, into a, b, c, d, g, etc., and a, b, e, f, i, etc.; and in Fig. 3, into a, b, c, f, g, etc., and a, d, e, h, i, etc. This method of calculation involves the supposition that in the first system (Fig. 2), the chord pieces, bd, dh, cg, etc. remain straight, making angles with each other at the joints c, d, g, h; while

in the second system the chord pieces, *ae*, *bf*, *ei*, etc. are supposed to remain straight, making angles with each other at *e*, *f*, etc. These two suppositions being in direct opposition, it is easily seen that the ordinary method of calculation is not exact, the systems being really statically undetermined. It can be shown, however, as it is important to remark, that the error made in calculating these trusses in the ordinary way is small enough to be neglected.

There will be occasion to refer briefly, on a subsequent page, to the arguments for and against systems which are statically undetermined. The weight of opinion among those best acquainted with the subject, seems to be that they are not to be recommended, except in cases like those just examined, where the error of an ordinary calculation is very small, and where practical advantages are gained by their use. Nevertheless, they are sometimes applied from choice, and sometimes almost from necessity. The simple method which will be explained, and by means of which they may be calculated, will commend itself to all.

Before proceeding, we may remark that it is easy to discover the conditions under which frames supported at one point (or rather one surface or support), or at more than two, are statically determined as regards the outer forces. Thus a frame supported at one point has only one reaction, and to determine that reaction completely, four quantities must be known, viz.: its two components, and the two co-

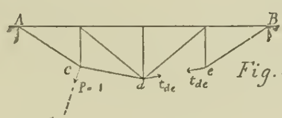


Fig. 4

ordinates of its point of application. Three equations being given by statics, one other condition is necessary, and this may be given in various ways. A frame supported at n places, like a continuous girder of n—1 spans, has n reactions, to determine which, $4n$ quantities are necessary. If the point of application of each reaction is given, and if all but one are vertical, we have $3n-1$ conditions; but it is necessary to have $4n$—3 conditions hence $n-2$ additional conditions are necessary, and these are given, in the ordinary method of treatment, by the theorem of three moments, which gives exactly n—2 elastic conditions.

II. Elastic Deflection of Frames.

Consider the bridge truss represented in Fig. 4, supported at A and

B, and let it be required to find the elastic deflection of any joint C, in any direction, $C\,G$, the loading being given. This deflection is due solely to the changes of length of the bars composing the frame, and if we can determine the effect of the change of length of each bar separately, our problem will be solved. This is done in the following manner: suppose a force P, equal to unity to be applied at C, in the direction $C\,G$, and to be the only load on the truss; and let the stresses produced by this force in the bars of the frame, be represented by t_{de}, etc. These stresses may be determined statically, in this case, as the system satisfies equation (1). Suppose, for a moment, all the bars except de to be perfectly rigid, not changing their lengths at all, and let de be removed, and the two forces, t_{de} be applied as represented at d and e. We have, then, a frame acted upon by the reactions at A and B, and by the following other forces: unity at C, t_{de} at d, and t_{de} at e, in the directions indicated in the figure. By the principle of virtual velocities, for a very small deformation, the work done by these forces must equal zero; or, as the reactions do no work, that done by P must equal that *done against* t_{de}: in other words, if P produce tension in de, as in the figure, the length de is increased, and the work done by P must equal the work done in extending the bar de. If we call $\varDelta_{de}$ the deflection of C along $C\,G$, and if we suppose the load P applied gradually, so as to cause no vibration, the average value of the load at C is $\frac{1}{2}\,P$, and the work done is $\frac{1}{2}\,P\varDelta_{de}$; or, as $P=1$, the work is $\frac{1}{2}\,\varDelta_{de}$. The average value of the stress in de is $\frac{1}{2}\,t_{de}$, and the work done is $\frac{1}{2}\,t_{de}\,\varDelta\,l_{de}$, if $\varDelta\,l_{de}$ is the change of length of de. Hence

$$\tfrac{1}{2}\,\varDelta_{de}=\tfrac{1}{2}\,t_{de}\,\varDelta l_{de},\text{ or }\varDelta_{de}=t_{de}\,\varDelta l_{de} \qquad (2)$$

Now it is clear that $\varDelta_{de}$ depends only on the change of length $\varDelta l_{de}$ of the bar de. If that change of length is, say, one inch, then it matters not how it is produced,—whether by loads, temperature, or any other cause,—the deflection of the point C will be the same. Hence, if we represent by $\varDelta l_{de}$ the real change of length of de, which is caused by any forces, or in any way whatever, $\varDelta_{de}$ will still be given by the same equation. Consequently, if we wish to find for given loading, the deflection of C along $C\,G$, we can find that part of it which is due to the bar de from equation (2), which becomes $\varDelta_{de}=t_{de}\left(\frac{sl}{FE}\right)_{de}$, s being the stress produced by the given loads, l the length, F the section, and E

the modulus of elasticity, all referring to de. One point must be carefully noticed as regards this equation, namely, that if Δ_{de} is to be positive, that is, if C is to move toward G, the change of length de, must be in the same direction as that due to t_{de}. If t_{de} is a tension, while the given loads cause compression, Δ_{de} will be negative. It is only necessary, in calculating t_{de} and s_{de}, to assume tension as positive, and compression as negative, and if all the signs are carefully observed, the result will be correct. In order, then, to find the total deflection of C, due to the changes of length of all the bars of the frame, we must only calculate the value of the expression in the above equation, for all the bars, or we have

$$\Delta = \Sigma t . \frac{sl}{FE}. \qquad (3)$$

This equation is perfectly general in its application, giving us with almost absolute accuracy, the *elastic* deflection in any direction of any point of a *framed* structure, truss, pier, arch, suspension system, etc. We say with *almost* absolute accuracy, simply because as the frame changes its shape the stresses in the bars become slightly different, and this change of stress is of course neglected. In order to find the absolute elastic deflection of any point, it is only necessary to find its deflections in two directions at right angles to each other. Their resultant gives the true deflection.

The equation above involves the section and modulus of elasticity of every bar in the frame, and, unless these are known, the deflection cannot be calculated. Hence we see why in cases when the equation is to be used as a means of calculating the stresses in frames, inasmuch as here the stresses and sections of the bars are the very quantities to be determined, a method of successive approximation must be resorted to, by first calculating the sections by some approximate method, and afterwards correcting them.

The fraction $\frac{s}{F}$ is the stress per square unit caused by the *given load*, but is evidently not constant.

One other source of error in the equation must be noticed, namely, that it does not take account of the shortening of length due to the bending of compressed pieces. This error cannot be corrected without introducing considerable complication, and perhaps not at all, but it is probably not very large in ordinary cases.

The use of the equation may be illustrated by some examples. Let us take first the frame shown in Fig. 5, loaded at the point A, with a force P, and let it be required to find the vertical deflection of this point. Suppose first the bar BC to be inelastic, or absent, the horizontal

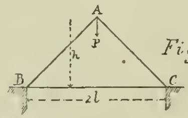


Fig. 5

thrust at B and C being supplied by unyielding abutments. Then

we have $$t_{ba}=t_{ca}=\frac{1}{2}\,\frac{\sqrt{l^2+h^2}}{h},$$

and $$s_{ba}=s_{ca}=\frac{P\sqrt{l^2+h^2}}{2h},$$

hence $$\Delta=2\,\frac{P.(l^2+h^2)^{\frac{3}{2}}}{4h^2F_{ab}E_{ab}}=\frac{P.(l^2+h^2)^{\frac{3}{2}}}{2h^2F_{ab}E_{ab}}.$$

This is the same expression, which was found in a more round-about way, by Prof. DuBois, on page 124 of this JOURNAL, for February, 1882.

If we suppose BC to be elastic, we have

$$\Delta=\frac{P\,(l^2+h^2)^{\frac{3}{2}}}{2h^2F_{ab}E_{ab}}+\frac{P\,l^3}{2h^2F_{bc}E_{bc}},\ \text{or, if } E_{ab}=E_{bc}=E,$$

$$\Delta=\frac{P}{2h^2E}\left[\frac{(l^2+h^2)^{\frac{3}{2}}}{F_{ab}}+\frac{l^3}{F_{bc}}\right].$$

In applying the method to bridge trusses with many pieces, it is best to arrange the result in tabular form. As an example, take one truss of the Broadway bridge, in Boston, as shown in Fig. 6, with

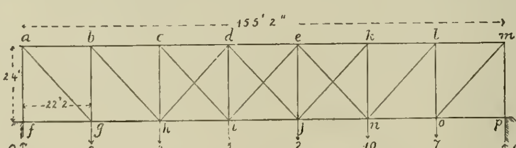


Fig. 6

the given loading. The span is 155 feet 2 inches, and the sections and lengths of the bars are given in the following table. Let it be required to find the vertical deflection of the point h. We first fill out the first four columns of the table, from the known data, then find

Bar.	Length l Inches	Section F Sq. ins.	Modulus of Elasticity, E. Tons per sq. inch.	t. Tons.	s Tons.	$\frac{1}{E}$	$\frac{ts}{F}$	$\Sigma \frac{tsl}{EF}$
ab	266	36·0	12,500	—0·66	— 8·316	0·02128	+0·1525	
bc	"	38·15	"	—1·32	—14·784	"	+0·5115	
cd	"	59·56	"	—1·056	—19·404	"	+0·3440	
de	"	59·56	"	—0·792	—22·176	"	+0·2949	
ek	"	59·56	"	—0·528	—23·100	"	+0·2048	
kl	"	38·15	"	—0·528	—23·100	"	+0·3197	
lm	"	36·0	"	—0·264	—14·784	"	+0·1084	
fg	"	12·25	"	0	0	"	+0	0·0983
gh	"	15·75	"	+0·66	+ 8·316	"	+0·3485	
hi	"	27·00	"	+1·32	+14·784	"	+0·7228	
ij	"	28·70	"	+1·056	+19·404	"	+0·7140	
jn	"	27·00	"	+0·792	+22·176	"	+0·6505	
no	"	15·75	"	+0·264	+14·784	"	+0·2478	
op	"	12·25	"	0	0	"	+0	
af	288	30·00	"	—0·71	— 9·00	0·02304	+0·213	
bg	"	21·00	"	—0.71	— 7·00	"	+0·2367	
ch	"	13·80	"	+0·29	— 5·00	"	—0·1051	
di	"	10·80	"	—0·29	— 3·00	"	—0·0806	0·012
ej	"	10·80	"	+0·29	— 1·00	"	—0·0269	
kn	"	13·80	"	0	0	"	+0	
lo	"	21·00	"	—0·29	— 9·00	"	+0·1243	
mp	"	30·00	"	—0·29	—16·00	"	+0·1547	
ag	392	23·75	"	+0·966	+12·24	0·03136	+0·498	
bh	"	16·88	"	+0·966	+ 9·52	"	+0·5448	
ci	"	10·12	"	—0·394	+ 6·80	"	—0·2647	
ah	"	1·23	"	0	0	"	+0	
dj	"	4·38	"	—0·394	+ 4·08	"	—0·367	0·0195
el	"	4·38	"	0	0	"	+0	
en	"	1·23	"	—0·394	+ 1·36	"	—0·4356	
kj	"	10·12	"	0	0	"	+0	
nl	"	16·88	"	+0·394	+12·25	"	+0.286	
om	"	23·75	"	+0·394	+21·76	"	+0·361	
							$\Delta = \Sigma \frac{tsl}{EF} =$	0·1297″

the stresses t, due to a vertical load unity in h, and finally the stresses s, due to the given loading. In calculating the stresses t, those bars are to be considered as in action which are really in action *under the given loading,* although they would not be the ones really acting if a load were to act in h alone. Assuming the modulus of elasticity to be 25,000,000 pounds per square inch, the resulting value of the deflection of the point h is a little over one-eighth of an inch. It is interesting to observe the relative effects of the chords and the web.

Leaving out the web members, the deflection is found to be 0·0983 inch, or about one-tenth of an inch. The relative effect of chords and web is as ·0983 to ·0314, or about as 3 to 1. It is therefore hardly correct, judging from the case, to neglect the influence of the web on the deflection, as is done, for instance, in most cases, in the treatment of continuous girders and framed arches. Some method seems to be called for by which each bar can be considered, and such a method is that afforded by the application of the principles which have been explained.

Having shown how to find the elastic deflection of any point in a frame which is statically determined, we may proceed to cases where a determination of deflection is involved, or those where the frame is statically undetermined regarding either the outer or the inner forces. Let us consider first the case where there is difficulty regarding the outer forces, or reactions. We have already seen that we must have three conditions involving the unknown quantities, in order to be able to find the reactions completely. If we support the truss in such a way that the points of application of the reactions are known, we have two of the necessary conditions (confining ourselves, as before, to a frame lying in the plane of the outer forces, and supported at two points), or if we introduce a hinge at any point in the frame, so that a section through this hinge divides the frame completely, without cutting any other bars, then the condition that the moment of the outer forces about the hinge is zero, is one of the conditions sought. By putting in three hinges, then, we supply three conditions, and are enabled to solve the problem by the use of statics alone, without the aid of the theory of elasticity.

The principal cases of frames supported at two points are the simple truss and the various forms of arches. In the simple truss we have the two points of application of the reactions, and the condition $H_2 L f V_2$, f being the co-efficient of friction, and the end where R_2 acts

being free to move horizontally, while the other end is fixed. In the arch hinged at crown and springing, also, we have the three conditions given; these two cases need not therefore be dwelt upon, and there remain only the cases of arches with fewer than three hinges.

We confine our attention to the effect of the elastic deflection.

III. The Arch Hinged at Springing.

We consider under this head the case of the arch hinged at each springing point. Only one additional condition is required in order

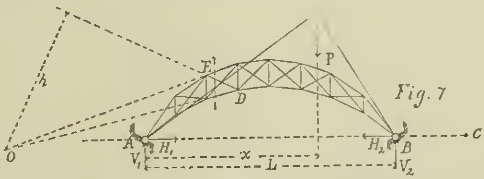


Fig. 7

to find the reactions, and this condition is that the change of the span under loads is either zero or a known quantity. This change of span is the horizontal deflection of the point B. Hence a solution of the question involves a consideration of the principles just discussed. Confining ourselves to the case where AB is horizontal, and the loads acting on the arch vertical, as is usually the case, we see at once that $H_1 = H_2 = H$, and that the vertical reactions are the same as for a simple girder, or distributed according to the law of the lever. Thus for a load P, at a distance x from A, $V_1 = P.\frac{L-x}{L}$. $V_2 = P\frac{x}{L}$. The only unknown quantity is H, which may now be easily found. Let us suppose first that the arch is supported by vertical reactions, or that $H = o$, and let it be loaded in any way desired. The point A, being fixed, B will move outward a distance $\Delta L_v = \Sigma t \frac{s_v l}{FE}$, according to equation (3). In this equation, E is the modulus of elasticity, F the cross-section, and l the length of any bar; s_v the stress produced in it by the given vertical loads, and t the stress produced in it by a horizontal force unity acting in B, and *outwards* towards C (the corresponding reaction acting outwards in A). This is clear from what has preceded. Now if the span is to remain constant, the horizontal thrust H, acting in B, towards A, must be sufficient to bring the point B back to its original position. Suppose H to be the only force acting, and let the

stresses which it causes in the bars be denoted by s_h. Then the horizontal deflection of B towards A, is

$$\Delta L_h = \Sigma - t\frac{s_h l}{FE},$$

because we must put instead of t the stresses produced by a load unity in B acting inward, or $-t$. We also have $s_h = -tH$, hence

$$\Delta L_h = H\Sigma\frac{t^2 l}{FE}.$$

Placing ΔL_v and ΔL_h equal to each other, and calling E constant, we have

$$\frac{1}{E}\Sigma\frac{t.s_v.l}{F} = \frac{H}{E}\Sigma\frac{t^2 l}{F},$$

or
$$H = \frac{\Sigma\frac{t.s_v.l}{F}}{\Sigma.\frac{t^2 l}{F}} \tag{4}$$

This equation applies when the abutments are immovable. If A and B are connected by a rod of section F_1, and modulus of elasticity E_1, its length being L, then its change of length, which is the deflection of B outward, is known, and given by the equation

$$\Delta L = \frac{HL}{F_1 E_1} \tag{5}$$

We have, then, in this case,

$$\Delta L_v = \Delta L_h + \Delta L,$$

or
$$\Sigma\frac{t.s_v l}{FE} = H\Sigma\frac{t^2.l}{FE} + \frac{HL}{F_1 E_1} \tag{6}$$

whence
$$H = \frac{\Sigma\frac{t.s_v l}{FE}}{\Sigma\frac{t^2 l}{FE} + \frac{L}{F_1 E_1}} \tag{7}$$

and, if E is constant,
$$H = \frac{\Sigma\frac{t\, s_v l}{F}}{\Sigma\frac{t^2 l}{F} + \frac{L}{F_1}} \tag{8}$$

H being found, the real stress in any bar is

$$S = s_v - t\ H \tag{9}$$

These simple equations suffice for the solution of this case. The tabular form is the best for computation, and the signs of the stresses must be carefully observed. A discussion of the best methods of finding the maximum stress in each bar of the frame does not belong here.

It is interesting, however, to note one transformation of equation (4). That equation may be written

$$\Sigma \frac{tl}{F} [s_v - tH] = o \tag{10}$$

or, according to equation (9)

$$\Sigma \frac{tlS}{F} = \Sigma t . \Delta l = o \tag{11}$$

S being the real stress in any bar, and Δl its change of length. But $S = \frac{M}{h}$, M being the moment about the origin of moments for the bar considered, and h the lever arm of that bar. Also, $t = \frac{Z}{h}$, z being the ordinate above AB of the origin of movements. Inserting these values in equation (11) we have

$$\Sigma \frac{M z l}{F h_2} = o \tag{12}$$

If we neglect entirely the influence of the web members, the summation extends only over the chord pieces, and z is the ordinate of a joint, while h is the distance between the chords. At any point, the moment of inertia of the chord sections about an axis midway between them is approximately

$$I = 2F . \frac{h^2}{4} = \tfrac{1}{2} F h^2.$$

Hence we have

$$\Sigma \frac{M z l}{I} = o. \tag{13}$$

The analogy of this equation to that which is often given for solid arches, namely $\int \frac{M}{I} z \, ds = o$, is apparent. It must not be forgotten, however, that it is not accurate.

(To be continued.)

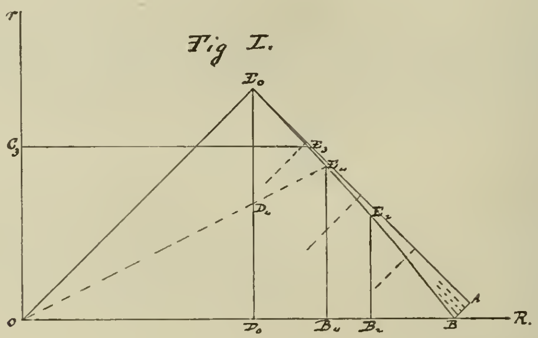
CONE PULLEYS.

By H. W. Spangler,
Assistant Engineer U. S. Navy.

The writer, in attempting to solve the problems arising in designing a pair of cone pulleys, with open belts, tried to use some one of the methods already known, but found that these methods were too complicated, too inaccurate, or not of sufficient range to cover all cases liable to arise.

Two of these methods are intended to solve the problems completely. One, by Prof. J. P. Klein, of Lehigh University, was published in a series of articles in the *American Machinist*, Vol. 2. The tables there given will give good results if used correctly; but unfortunately, five out of seven cases, which are solved by the computer himself, give incorrect results. Evidently the tables are not just what is required.

Fig I.



The other method referred to is one published by Mr. Nystrom, in the first volume of Mechanics. This method is not complete, as it requires that the diameter of the pulley, which is to be the same on each shaft, shall be known, and it is also a long method of getting at a simple result.

The application of the method arrived at by the writer is given first and the proof afterwards.

The following notation is used: a, Fig. 2, is the perpendicular distance between the shafts. R and r are the radii of any two pulleys connected by the belt, R being the larger. R_0 is the value of R when $R=r$.

First calculate the value of R_0, having any two corresponding radii R and r given, from the formula

$$R_0 = \frac{R+r}{2} + \cdot 15915 \frac{(R-r)^2}{a}.$$

Having assumed or calculated this value, draw two lines, $O\ R$ and $O\ r$, at right angles to each other, Fig. 1. Lay off $O\ D_0 = R_0$ along $O\ R$ and draw $D_0\ E_0$ parallel to $O\ r$ and equal to R_0. Draw $o\ E_0$.

Calculate the distance

$$O\ B = \sqrt{6 \cdot 2832 \times a \times R_0 + 2 \cdot 4674 \times a^2} - 1 \cdot 5708 \times a,$$

and mark the point B. Draw, through E_0, the line $A\ E_0$ at right angles to $O\ E_0$, and through B draw $B\ A$ parallel to $O\ E_0$. Divide $A\ E_0$ into any number of equal parts and $A\ B$ into the same number. Through the divisions of $A\ E_0$ draw lines parallel to $O\ E_0$ and join the divisions of $A\ B$ to E_0. Where these two sets of lines meet are points in the arc of a parabola passing through B and E_0 and having $O\ E_0$ for an axis. If the divisions of $E_0\ A$ are not over an inch apart, the diagram being drawn full size, the points found can be joined by a broken line without giving rise to an appreciable error.

Having drawn the curve, the radii of any corresponding pulleys can be measured from it as follows. Having given one radius as R_2, greater than R_0, lay it off along $O\ R$ to B_2. Erect the perpendicular

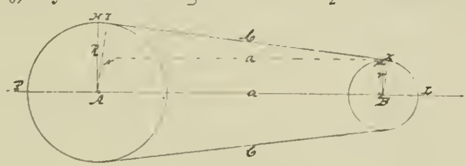


FIG. 2.

$B_2\ E_2$ and this line is the radius r_2 corresponding to R_2. If a radius r_3 less than R_0 is given, draw $O\ C_3$ equal to r_3, and through C_3 draw $E_3\ C_3$ parallel to $O\ R$. $E_3\ C_3$ is the radius, R_3 corresponding to r_3.

If it is required that two pulleys, R_4 and r_4, shall have certain relative diameters or radii, divide $D_0\ E_0$ in the ratio of the radii so that $\frac{D_0\ E_0}{D_0\ D_4} = \frac{R_4}{r_4}$. Draw $D_4\ O$ and $r_4 = E_4\ B_4$ and $R_4 = B_4\ O$.

The length of the belt can be found from the formula

$$6 \cdot 2832\ R_0 + 2a.$$

PROOF.

Let A and B, Fig. 2, be any two corresponding pulleys, whose radii are R and r, connected by the open belt $C'\ C$. Suppose the

distance between the centres of the pulleys to be a. The half-length of the belt is $L\ K\ I\ H\ F$.

$$L\ K = r\left\{\frac{\pi}{2} - \text{angle } M\ B\ K\right\}$$

$$K\ I = \sqrt{a^2-(R-r)^2}$$

$$I\ H\ F = R\left\{\frac{\pi}{2} + \text{angle } I\ A\ H\right\},$$

or the half-length of the belt is $r\left\{\frac{\pi}{2} - \text{angle } M\ B\ K\right\} + \sqrt{a^2-(R-r)^2}$ $+ R\left\{\frac{\pi}{2} + \text{angle } I\ A\ H\right\}$. The angle $M\ B\ K =$ angle $I\ A\ H =$ angle $I\ K\ N =$ arc sin. $\left(\frac{R-r}{a}\right)$, and the half-length of the belt is

$$(R+r)\frac{\pi}{2} + (R-r) \text{ arc sin.}\left(\frac{R-r}{a}\right) + \sqrt{a^2-(R-r)^2} \qquad (a.)$$

If, when $R=r$, we call the radius R_0, we leave for the half-length of the belt

$$R_0\,\pi + a$$

and the length of the belt is

$$2\,\pi\,R_0 + 2a = 6{\cdot}2832\ R_0 + 2a.$$

Going back to equation (a) arc sin. $\left(\frac{R-r}{a}\right) = \frac{R-r}{a} + \frac{(R-r)^3}{6a^3}$ $+ 3\,\frac{(R-r)^5}{40a^5}$ + etc., and $(R-r)$ arc sin. $\left(\frac{R-r}{a}\right) =$

$$\frac{(R-r)^2}{a} + \frac{(R-r)^4}{6a^3} + \frac{3(R-r)^6}{40a^5} + \text{etc.}$$

$$\sqrt{a^2-(R-r)^2} = a - \frac{(R-r)^2}{2a} - \frac{(R-r)^4}{8a^3} - \frac{(R-r)^6}{16a^5} - \text{etc.,}$$

and the half-length of the belt or $\pi\,R_0 + a =$

$$(R+r)\frac{\pi}{2} + \frac{(R-r)^2}{a} + \frac{(R-r)^4}{6a^3} + 3\,\frac{(R-r)^6}{40a^5} + \text{etc.} + a - \frac{(R-r)^2}{2a}$$

$$- \frac{(R-r)^4}{8a^3} - \frac{(R-r)^6}{16a^5} - \text{etc.} =$$

$$a + (R+r)\,\frac{\pi}{2} + \frac{(R-r)^2}{2a} + \frac{(R-r)^4}{24a^3} + \frac{(R-r)^6}{80a^5} + \text{etc.}$$

The terms $\frac{(R-r)^4}{24a^3} + \frac{(R-r)^6}{80a^5}$ + etc. can be omitted, because for all practical values of R, r, and a, their sum would be very small, and we have

$$\pi R_o + a = a + \frac{(R+r)\pi}{2} + \frac{(R-r)^2}{2a},$$

or

$$\pi R_o = \frac{(R+r)\pi}{2} + \frac{(R-r)^2}{2a}.$$

From this we get the equation

$$R_o = \frac{R+r}{2} + \frac{(R-r)^2}{2\pi a} = \frac{R+r}{2} + \cdot 15915 \frac{(R-r)^2}{a}.$$

If, as in Fig. 1, we take two lines at right angles to each other, and lay off on these lines distances equal to R as abscissæ and r as ordinates, the curve formed will be the curve whose equation is

$$\pi R_o = (R+r) \frac{\pi}{2} + \frac{(R-r)^2}{2a}. \qquad (b.)$$

This is the equation of a parabola whose principal axis is a line passing through O, Fig. 1, at an angle of 45° to $O\ R$ and $O\ r$, and whose vertex is at the point where $R=r=R_o$. In order to construct the curve one other point is required, and this can be found by putting $r=o$ and we have

$$\pi R_o = R \frac{\pi}{2} + \frac{R^2}{2a}.$$

Solving this equation for R gives

$$R = O\ B \text{ (Fig. 1.)} = \sqrt{2\pi a R_o + \frac{\pi^2 a^2}{4}} - \frac{\pi a}{2},$$

or $$O\ B = \sqrt{6 \cdot 2832 \times a \times R_o + 2 \cdot 4674 \times a^2} - 1 \cdot 5708 \times a.$$

Having found this point, the parabola can be constructed as shown before, and the co-ordinates of any point on it are the radii of corresponding steps of two cone pulleys.

It may not be readily seen that the equation (b) is the equation of a parabola, but if for R we put $(x+R_o)$ and for r we put $(y+R_o)$, the shape of the curve is not changed but the axes are moved parallel to themselves to the point E_o, and the equation (b) becomes

$$\pi R_o = (x + y + 2\ R_o) \frac{\pi}{2} + \frac{(x-y)^2}{2a},$$

or
$$2 \pi R_0 = \pi x + \pi y + 2 R_0 \pi + \frac{(x-y)^2}{a},$$

or
$$\frac{(x-y)^2}{a\pi} + x + y = O. \qquad (c.)$$

If in equation (c) we put for x the value $\left\{ \frac{x_1}{\sqrt{2}} + \frac{y_1}{\sqrt{2}} \right\}$, and for y the value $\left\{ \frac{x_1}{\sqrt{2}} - \frac{y_1}{\sqrt{2}} \right\}$, we change the direction of both axes 45°, but do not change the curve, which is still the same curve as given by equation (b).

Making these substitutions in (c) we have

$$\frac{(y_1 \sqrt{2})^2}{\pi a} + x_1 \sqrt{2} = O,$$

or
$$y_1^2 = - \frac{a\pi}{\sqrt{2}} x_1,$$

which is the well-known equation of a parabola having one of the axes of co-ordinates for a diameter, and having the vertex at the origin of co-ordinates; and the curve given by equation (b) must be a parabola whose axis is at 45° to $o\,R$ and whose vertex is at $R = r = R_0$.—*University of Pennsylvania, Philadelphia,* Dec. 14, 1882.

Argentine.—The product which is known in commerce under the name of argentine, and which is employed for printing upon cloths and paper, is a tin moss or sponge, obtained from the precipitation of a solution of chloride of tin by zinc. The solution, strongly acidulated at first, must be diluted until it contains 60 litres of water (15·85 gallons) for 150 grammes of the tin salt. The sponge must be collected with care and without compression in a sieve, then washed in water and dried by heat. It may then be finally brayed with water in a mortar, passed through a hair sieve and mixed with starch paste for printing. The small quantity of the sponge which remains upon the sieve is dissolved in a mixture of equal parts of chlorhydric acid and water and added to the tin solution. The same water may be used from ten to thirteen times. The chloride of zinc in solution may be evaporated and used for soldering or for cleansing objects which are to be tinned. The gray tin powder can be economically employed for tinning all metals but lead.—*Chron. Industr.*, Oct. 19, 1882. C.

DUST EXPLOSIONS IN BREWERIES.

By C. John Hexamer.

[A paper read at the stated meeting of the Franklin Institute held January 17, 1882.]

I do not, in this short paper, intend to give a detailed treatise concerning malt dust explosions, as in the September number of the Journal, a reprint of Prof. Tobin's address delivered before the "Fire Underwriters' Association of the Northwest," on "Explosive and Dangerous Dusts," gave a very clear outline of the subject. I shall, therefore, refrain from giving a series of experiments similar to those performed by him at the time, but shall directly go on to show that dust explosions in breweries may be largely prevented, and how, when they do occur, the explosive force and fire may be restricted to the mill-room.

The cause of the explosions in breweries is, that when grain dust becomes finely divided a certain degree of fineness is reached at which it may, on the slightest provocation, be almost instantaneously ignited, as for example, by the spark of a striking piece of iron, the products of the almost instantaneous combustion being gases of many hundred times the volume of the former dust, causing, by their expansion, the terrific force of these explosions. With the present arrangement of malt mills in breweries explosions and fires of this nature are not restricted to the mill-room, but spread through the elevators and openings, throughout the entire brewery, generally occasioning heavy losses. One of the greatest defects of the present system is that of having the mill inside of the main brewery building. This should be placed outside. It is just as dangerous, if not more so, to have the malt-mill in a brewery as it would be to have the picker of a shoddy mill in the main building. The first and cardinal change from the present system should be as follows:

The mill should be situated outside of the main brewery, in a separate building, all communicating openings between the mill-house and main building being closed by iron-lined doors, with stone sills, and the doors should be self-closing.

Having considered this defect we must next turn our attention to the construction of the mill-room, and the mill itself.

At present the malt-mill of the ordinary type consists of a cleaning

apparatus, frequently for dust only, a pair of chilled iron or steel rolls, sometimes corrugated, motion being imparted to but one, the other being turned by friction. The crushed grain drops from the rolls into the elevator cups and is then carried to the grain bin, generally situated on one of the higher floors. Now, let us closely look at this arrangement and examine its defects. The malt after passing through, even the best cleaner, still contains extraneous particles of iron, but with the ordinary cleaning apparatus the grain is full of such particles as stones, iron nails, bits of wire, from "self-binders and reapers," matches, and I was even informed of a case where a loaded pistol cartridge was happily detected before passing into the mill. In case a piece of iron comes between the revolving rolls it is apparent that a spark is readily created, which instantly inflames the finely divided dust in the mill-box, causing an explosion and fire. But the explosion must find vent somewhere, so it travels up the elevator boot, being in fact sucked up the boot by the upward draft in it, caused by the upward motion of the cups, acting like so many fans. The boot which is filled with very dry dust, having lost much moisture by passing through the rolls, is thereby also ignited, carries the fire from story to story, while the elevator-box, which is almost without exception, of wood, is rapidly burned through, and thus an entire building may become a prey to the flames. Having considered the defects of a system which has of late caused most of our brewery fires, let us next consider how to overcome them.

The grain should be thoroughly cleaned before passing into the mill; this may be accomplished by a number of devices, the simplest being a cylindrical (or hexagonal) screen with meshes of unequal sizes. One-half contains meshes large enough to allow dust to pass, while in the other half the size of the meshes is increased so as to allow the passage of grain, retaining, however, all larger and irregularly formed foreign matter. The grain, after passing into the cylinder, is rolled about by the revolution of the screen; the malt dust falls through the small meshes, the grain passes into the second half containing the larger meshes, where larger foreign matter is retained, and shot out into a bag at the other end, while the grain falling through the meshes drops into the rolls. Many other, but more complicated, processes may be employed for this purpose, among which may be mentioned those of Haas & Parson and Schwalbe & Son.

The latter, which also, besides cleaning, classifies the grain, is deserv-

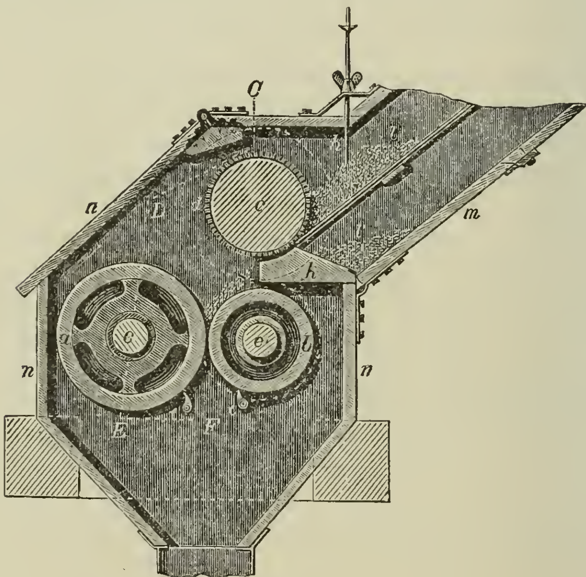
ing of special mention; although it has in Germany been almost exclusively employed to clean and classify the grain before malting, yet it would be an excellent cleaner for malt before milling, as it would be very desirable to mill malt of one size and quality (which varies with the size) at one time, both for *setting* the mill and for better results in the "mash." [*Representations of various cleaning machinery were here thrown on the screen and explained.*]

Grain should be especially well cleaned of *all* iron particles, as it is these which—by striking a spark—create most explosions and fires in malt mills. Iron can only be effectually eliminated from the grain by a *strong* magnet. A weak magnet will not answer, as the magnetic force must overcome the momentum with which the grain runs down the spout into the mill. Magnets may be arranged either in the form of horse shoes through which the grain runs, or as a single very strong "plate magnet." The latter method is preferable, as the number of smaller horse shoe magnets will not have the same amount of attractive force as *one* large plate magnet.

The grain, after being well cleaned and all the remaining iron removed by the magnet, is passed into the rolls. As these are well known, we will not take the space to describe them here, but simply state that they should be gearing, *not friction rolls.* In the case of friction rolls, motion is imparted to but one roll, the other being turned by the friction of the passing grain. In gearing rolls, to the contrary, the rolls are driven by gearing, and therefore both have their own motive power. In the first case, a piece of iron or stone coming between the rolls would cause a large amount of frictional heat, producing a spark and perhaps an explosion. In the second case the rolls, by the motive power which both have, would be more likely to have sufficient power to crush or flatten any extraneous particle without the production of enough frictional heat to cause an explosion. To still lessen the chances for the creation of heat the rolls should be held together by powerful springs, strong enough to allow grain to be crushed, but separating on the entrance of some harder body, such as a piece of stone or iron. At present most malt mills, and, with one exception, all malt mills in Philadelphia have their rolls held together by "set screws," which are arranged so as to set the rollers at any desirable distance apart; in case a hard extraneous substance comes between the rolls there is no "*give*," the only chance of stopping the

enormous friction between the hard substance and rolls will consist in the breaking of the screws or the crushing of the substance.

The great danger in malt mills is that, in case of an explosion, the explosive force and fire is not confined to the mill only, but runs from the mill into the elevator, and from there is distributed over the entire building. To check the force and fire of an explosion we must put a barrier between the mill-box and the elevator. This can best be accomplished by placing a receiving hopper below the rolls, kept well



G

filled while the mill is in operation, and from this hopper feed into the elevator cups. We thereby have a barrier of meal between the elevator and the mill, a barrier almost as effective as one of sand. But the important point in this case will be to keep the hopper well filled, for a hopper which is not full merely acts as a conduit and not as a barrier to an explosion. In order that the attendant of a mill shall not be relied upon, the receiving hopper should be kept filled automatically. For this purpose I suggested the following device, shown in the cut, (Fig. 1); a device which was not a new invention, but an adaptation of something well known, for a new purpose. A "feeder" for grain mills used for a long time in Germany is shown in cut, e and e^1 being the rolls of the mill, n, n, being the mill-box, while G is the

spout ordinarily leading into the elevator boot in mills properly constructed, into a receiving hopper; *c* is a roll of wood usually covered with a covering, and teeth *d* of steel projecting from 2 to 3 millimeters, we propose to use a covering and teeth of copper, phosphor bronze, or some other metal which will strike no sparks; *l* is an inclined plane of metal with sieve-like perforations large enough to allow dust to drop through them; *h* is a gauge which regulates the flow of grain on to the feeding roll *c*; l^1 is a "dust chamber," which may be made of any size, and which may be cleaned out through the door *m*; *k* is the receiving block of wood covered with copper, and at a distance of 1.9 millimeters from the teeth of the feeding roll. The operation of this feeder, which is a Belgian invention, and which has been used with great success in Germany, is very simple. The grain after passing through a cleaner drops on to the incline, is there separated from any remaining dust; and is then allowed to run in a thin stream—regulated by the gauge—on to the receiving block, where it is fed into the mill by the revolution of the feeding roll. We propose to utilize this invention, modified as above, to keep our receiving hopper at all times full. The crushed grain instead of falling directly into the elevator cups on leaving *G*, will fall into a receiving hopper, from which a pipe or incline (without perforations) leads the meal past a gauge, on to a feeder as described above, where the meal is fed into a smaller hopper, from which it drops into the elevator. On setting up a mill the relative points for both gauges will be determined, the grain-feeder and the mill will be set in motion while the *discharger* will remain at rest until the receiving hopper is filled, when it will also be set in motion; this operation will be performed by the erecting machinist; for after the first grinding the receiving hopper will always be full, as the grain will be fed in just as rapidly at the top as the meal is discharged at the bottom. The only case in which the receiving hopper could become empty is one, which would very rarely occur in a well-conducted brewery; that is when the mill is running while no grain is on the incline. When this does occur the above described process must be repeated.

The receiving hopper and elevator should be lined, so that in case of fire the flames may be restricted to them. The lining of the elevator box should, however, not be of iron but copper, as the elevator cups, on striking against an iron lining, might readily create a spark.

That the force of explosions may be spent without harming the

building, large vent pipes—leading into the open air—should be introduced into the mill-box. Iron pipes closed on the outside by caps, similar to our common stove pipe hole caps—which in case of an explosion would be readily blown off—would be the most effectual.

Steam jets should be introduced into both the mill-box and elevator. One of our breweries has extinguished two explosive malt mill fires by this means.

The compartment appropriated for the use of the malt mill should be well lighted, so that no artificial light may be required on the cloudiest day. Where night work is in vogue, or where artificial light is required for day work, the light should be enclosed, and *under no condition should loose candles or coal oil lamps* be employed.

I will not take up your valuable time in describing other minor devices, which I have invented, such as an automatic contrivance by which I close all communicating openings between the mill-house and the brewery, and turn on the steam by the pressure of the explosions. I am satisfied, however that in a brewery in which my system of milling is introduced, explosions will be almost entirely prevented, and when these do occur, they will be restricted to the mill-room without doing further harm.

Effect of Light upon Glass.—Some kinds of white glass become, in the process of time, more or less deeply colored under the influence of luminous rays. The most common tints are violet and green. The materials of ordinary glass are somewhat ferruginous and capable of tinging glass with a deep green shade by the protoxide of iron. In order to remove the coloring, peroxide of manganese is added, which changes the protoxide into a sesqui oxide, which gives a feeble reddish-yellow tint. It is almost impossible to observe the proper proportions of manganese and iron. If there is too much oxide of manganese the glass has at first a violet shade; if there is too much protoxide of iron the glass will be greenish; if all the manganese is reduced to the state of protoxide the glass is colorless. The influence of light and air may gradually bring about a partial oxidation of the protoxide of manganese and a violet coloring which increases with time. A shade which is due to an excess of manganese is observed in the Pinacothek, at Munich, where the upper windows of the picture gallery give a very marked violet light which produces a bad effect.—*Polyt. Ztg.* cited in *Chron. Indust.*, No. 41.

SCIENCE IN RELATION TO THE ARTS.

By C. William Siemens, F. R. S.

(Continued from page 66.)

The demand for ammonia may be taken as unlimited, on account of its high agricultural value as a manure; and, considering the failing supply of guano and the growing necessity for stimulating the fertility of our soil, an increased production of ammonia may be regarded as a matter of national importance, for the supply of which we have to look almost exclusively to our gas works. The present production of 1,000,000 tons of liquor yields 95,000 tons of sulphate of ammonia; which taken at 20*l*. 10*s*. a ton, represents an annual value of 1,947,000£.

The total annual value of the gas works by-products may be estimated as follows:

Coloring matter, ...	£3,350,000
Sulphate of ammonia, ...	1,947,000
Pitch (325,000 tons)	365,000
Creosote (25,000,000 gallons) . . .	208,000
Crude carbolic acid (1,000,000 gallons) . . .	100,000
Gas coke, 4,000,000 tons (after allowing 2,000,000 tons consumption in working the retorts) at 12*s*. . .	2,400,000
Total	£8,370,000

Taking the coal used, 9,000,000 tons at 12*s*., equal 5,400,000*l*., it follows that the by-products exceed in value the coal used by very nearly 3,000,000*l*.

In using raw coal for heating purposes these valuable products are not only absolutely lost to us, but in their stead we are favored with those semi-gaseous by-products in the atmosphere too well known to the denizens of London and other large towns as smoke. Professor Roberts has calculated that the soot in the pall hanging over London on a winter's day amounts to fifty tons, and that the carbonic oxide, a poisonous compound, resulting from the imperfect combustion of coal, may be taken as at least five times that amount. Mr. Aitken has shown, moreover, in an interesting paper communicated to the Royal Society of Edinburgh, last year, that the fine dust resulting from the imperfect combustion of coal is mainly instrumental in the formation

of fog; each particle of solid matter attracting to itself aqueous vapor; these globules of fog are rendered particularly tenacious and disagreeable by the presence of tar vapor, another result of imperfect combustion of raw fuel, which might be turned to much better account at the dye-works. The hurtful influence of smoke upon public health, the great personal discomfort to which it gives rise, and the vast expense it indirectly causes through the destruction of our monuments, pictures, furniture, and apparel, are now being recognized, as is evinced by the success of recent Smoke Abatement Exhibitions. The most effectual remedy would result from a general recognition of the fact that wherever smoke is produced, fuel is being consumed wastefully, and that all our calorific effects, from the largest down to the domestic fire, can be realized as completely and more economically, without allowing any of the fuel employed to reach the atmosphere unburnt. This most desirable result may be effected by the use of gas for all heating purposes with or without the addition of coke or anthracite.

The cheapest form of gas is that obtained through the entire distillation of fuel in such gas producers as are now largely used in working the furnaces of glass, iron, and steel works; but gas of this description would not be available for the supply of towns owing to its bulk, about two-thirds of its volume being nitrogen. The use of water-gas, resulting from the decomposition of steam in passing through a hot chamber filled with coke, has been suggested, but this gas also is objectionable, because it contains, beside hydrogen, the poisonous and inodorous gas carbonic oxide, the introduction of which into dwelling-houses could not be effected without considerable danger. A more satisfactory mode of supplying heating separately from illuminating gas would consist in connecting the retort at different periods of the distillation with two separate systems of mains for the delivery of the respective gases. Experiments made some years ago by Mr. Ellisen of the Paris gas works have shown that the gases rich in carbon, such as olefiant and acetylene, are developed chiefly during an interval of time, beginning half an hour after the commencement and terminating at half the whole period of distillation, whilst during the remainder of the time, marsh gas and hydrogen are chiefly developed, which, while possessing little illuminating power, are most advantageous for heating purposes. By resorting to improved means of heating the retorts with gaseous fuel, such as have been in use at the Paris gas

works for a considerable number of years, the length of time for effecting each distillation may be shortened from six hours, the usual period in former years, to four, or even three hours, as now practiced at Glasgow and elsewhere. By this means a given number of retorts can be made to produce, in addition to the former quantity of illuminating gas of superior quality, a similar quantity of heating gas, resulting in a diminished cost of production and an increased supply of the valuable by-products previously referred to. The quantity of both ammonia and heating gas may be further increased by the simple expedient of passing a streamlet of steam through the heated retorts towards the end of each operation, whereby the ammonia and hydrocarbons still occluded in the heated coke will be evolved, and the volume of heating gas produced be augmented by the products of decomposition of the steam itself. It has been shown that gas may be used advantageously for domestic purposes with judicious management even under present conditions, and it is easy to conceive that its consumption for heating would soon increase, perhaps tenfold, if supplied separately at say 1*s.* a thousand cubic feet. At this price gas would be not only the cleanest and most convenient, but also the cheapest form of fuel, and the enormous increase of consumption, the superior quality of the illuminating gas obtained by selection, and the proportionate increase of by-products, would amply compensate the gas company or corporation for the comparatively low price of the heating gas.

The greater efficiency of gas as a fuel results chiefly from the circumstance that a pound of gas yields in combustion 22,000 heat units, or exactly double the heat produced by combustion of a pound of ordinary coal. This extra heating power is due partly to the freedom of the gas from earthy constituents, but chiefly to the heat imparted to it in effecting its distillation. Recent experiments with gas-burners have shown that in this direction also there is much room for improvement.

The amount of light given out by a gas flame depends upon the temperature to which the particles of solid carbon in the flame are raised, and Dr. Tyndall has shown that of the radiant energy set up in such a flame, only the $\frac{1}{25}$th part is luminous; the hot products of combustion carry off at least four times as much energy as is radiated, so that not more than one hundredth part of the heat evolved in combustion is converted into light. This proportion could be improved

however, by increasing the temperature of combustion, which may be effected either by intensified air currents or by regenerative action. Supposing that the heat of the products of combustion could be communicated to metallic surfaces, and be transferred by conduction or otherwise to the atmospheric air supporting combustion in the flame, we should be able to increase the temperature accumulatively to any point within the limit of dissociation; this limit may be fixed at about 2,300° C., and cannot be very much below that of the electric arc. At such a temperature the proportion of luminous rays to the total heat produced in combustion would be more than doubled, and the brilliancy of the light would at the same time be greatly increased. Thus improved, gas-lighting may continue its rivalry with electric lighting both as regards economy and brilliancy, and such rivalry must necessarily result in great public advantage.

In the domestic grate, radiant energy of inferior intensity is required, and I for one do not agree with those who would like to see the open fireplace of this country superseded by the continental stove. The advantages usually claimed for the open fireplace are, that it is cheerful, 'pokable,' and conducive to ventilation, but to these may be added another of even greater importance, viz. that the radiant heat which it emits passes through the transparent air without warming it, and imparts heat only to the solid walls, floor, and furniture of the room, which are thus constituted the heating surfaces of the comparatively cool air of the apartments in contact with them. In the case of stoves the heated air of the room causes deposit of moisture upon the walls in heating them, and gives rise to mildew and germs injurious to health. It is, I think, owing to this circumstance that upon entering an apartment one can immediately perceive whether or not it is heated by an open fireplace; nor is the unpleasant sensation due to stove-heating completely removed by mechanical ventilation; there is, moreover, no good reason why an open fireplace should not be made as economical and smokeless as a stove or hot-water apparatus.

In the production of mechanical effect from heat, gaseous fuel also presents most striking advantages, as will appear from the following consideration. When we have to deal with the question of converting mechanical into electrical effect, or *vice versâ*, by means of the dynamo-electrical machine, we have only to consider what are the equivalent values of the two forms of energy, and what precautions are necessary to avoid losses by the electrical resistance of conductors and by

friction. The transformation of mechanical effect into heat involves no losses except those resulting from imperfect installation, and these may be so completely avoided that Dr. Joule was able by this method to determine the equivalent values of the two forms of energy. But in attempting the inverse operation of effecting the conversion of heat into mechanical energy, we find ourselves confronted by the second law of thermo-dynamics, which says that whenever a given amount of heat is converted into mechanical effect, another but variable amount descends from a higher to a lower potential, and is thus rendered unavailable.

In the condensing steam engine this waste heat comprises that communicated to the condensing water, whilst the useful heat, or that converted into mechanical effect, depends upon the difference of temperature between the boiler and condenser. The boiler pressure is limited, however, by considerations of safety and convenience of construction, and the range of working temperature rarely exceeds 120° C. except in the engines constructed by Mr. Perkins, in which a range of 160° C., or an expansive action commencing at 14 atmospheres, has been adopted with considerable promise of success, as appears from an able report on this engine by Sir Frederick Bramwell. To obtain more advantageous primary conditions we have to turn to the caloric or gas engines, because in them the co-efficient of efficiency expressed by $\frac{T-T'}{T}$, may be greatly increased. This value would reach a maximum if the initial absolute temperature T could be raised to that of combustion, and T′ reduced to atmospheric temperature, and these maximum limits can be much more nearly approached in the gas engine worked by a combustible mixture of air and hydro-carbons than in the steam engine.

Assuming, then, in an explosive gas engine a temperature of 1,500° C. at a pressure of 4 atmospheres, we should, in accordance with the second law of thermo-dynamics, find a temperature after expansion to atmospheric pressure of 600° C., and therefore a working range of $1{,}500° - 600° = 900°$, and a theoretical efficiency of $\frac{900}{1500+274}$ = about one-half, contrasting very favorably with that of a good expansive condensing steam engine, in which the range is $150 - 30 = 120°$ C., and the efficiency $\frac{120}{150+274} = \frac{2}{7}$. A good

expansive steam engine is therefore capable of yielding as mechanical work $\frac{2}{7}$th part of the heat communicated to the boiler, which does not include the heat lost by imperfect combustion, and that carried away in the chimney. Adding to these, the losses by friction and radiation in the engine, we find that the best steam engine yet constructed does not yield in mechanical effect more than $\frac{1}{7}$th part of the heat energy residing in the fuel consumed. In the gas engine we have also to make reductions from the theoretical efficiency, on account of the rather serious loss of heat by absorption into the working cylinder, which has to be cooled artificially in order to keep its temperature down to a point at which lubrication is possible; this, together with frictional loss, cannot be taken at less than one-half, and reduces the factor of efficiency of the engine to $\frac{1}{4}$th.

It follows from these considerations that the gas or caloric engine combines the conditions most favorable to the attainment of maximum results, and it may reasonably be supposed that the difficulties still in the way of their application on a large scale will gradually be removed. Before many years have elapsed we shall find in our factories and on board our ships, engines with a fuel consumption not exceeding 1 pound of coal per effective horse power per hour, in which the gas producer takes the place of the somewhat complex and dangerous steam boiler. The advent of such an engine and of the dynamo-machine must mark a new era of material progress at least equal to that produced by the introduction of steam power in the early part of our century. Let us consider what would be the probable effect of such an engine upon that most important interest of this country—the merchant navy.

According to returns kindly furnished me by the Board of Trade and "Lloyds' Register of Shipping," the total value of the merchant shipping of the United Kingdom may be estimated at 126,000,000£. of which 90,000,000£. represent steamers having a net tonnage of 3,003,988 tons; and 36,000,000*l*. sailing vessels, of 3,688,008 tons. The safety of this vast amount of shipping, carrying about five-sevenths of our total imports and exports, or 500,000,000£. of goods in the year, and of the more precious lives connected with it, is a question of paramount importance. It involves considerations of the most varied kind: comprising the construction of the vessel itself, and the material employed in building it; its furniture of engines, pumps, sails, tackle, compass, sextant, and sounding apparatus, the preparation

of reliable charts for the guidance of the navigator, and the construction of harbors of refuge, lighthouses, beacons, bells, and buoys, for channel navigation. Yet notwithstanding the combined efforts of science, inventive skill, and practical experience—the accumulation of centuries—we are startled with statements to the effect that during last year as many as 1,007 British-owned ships were lost, of which fully two-thirds were wrecked upon our shores, representing a total value of nearly 10,000,000£. Of these ships 870 were sailing vessels and 137 steamers, the loss of the latter being in a fourth of the cases attributable to collision. The number of sailing vessels included in these returns being 19,325, and of steamers 5,505, it appears that the steamer is the safer vessel, in the proportion of 4·43 to 3·46; but the steamer makes on an average three voyages for one of the sailing ship taken over the year, which reduces the relative risk of the steamer as compared with the sailing ship per voyage in the proportion of 13·29 to 3·46. Commercially speaking, this factor of safety in favor of steam-shipping is to a great extent counterbalanced by the value of the steamship, which bears to that of the sailing vessel per net carrying ton the proportion of 3·1, thus reducing the ratio in favor of steam shipping as 13·29 to 10·38, or in round numbers as 4 to 3. In testing this result by the charges of premium for insurance, the variable circumstances of distance, nature of cargo, season and voyage have to be taken into account; but judging from information received from shipowners and underwriters of undoubted authority, I find that the relative insurance paid for the two classes of vessel represents an advantage of 30 per cent. in favor of steam-shipping, agreeing very closely with the above deductions derived from statistical information.

In considering the question how the advantages thus established in favor of steam-shipping could be further improved, attention should be called in the first place to the material employed in their construction. A new material was introduced for this purpose by the Admiralty in 1876–78, when they constructed at Pembroke dockyard the two steam corvettes, the *Iris* and *Mercury*, of mild steel. The peculiar qualities of this material are such as to have enabled shipbuilders to save 20 per cent. in the weight of the ship's hull, and to increase to that extent the carrying capacity. It combines with a strength 30 per cent. superior to that of iron, such extreme toughness, that in the case of collision the side of the vessel has been found to yield or bulge several feet without showing any signs of rupture, a quality affecting

the question of sea risk very favorably. When to the use of this material there are added the advantages derived from a double bottom, and from the division of the ship's hold by means of bulkheads of solid construction, it is difficult to conceive how such a vessel could perish by collision either with another vessel or with a sunken rock. The spaces between the two bottoms are not lost, because they form convenient chambers for water ballast, but powerful pumps should in all cases be added to meet emergencies.

The following statement of the number and tonnage of vessels building and preparing to be built in the United Kingdom on the 30th of June last, which has been kindly furnished me by Lloyd's, is of interest as showing that wooden ships are fast becoming obsolete, and that even iron is beginning to yield its place, both as regards steamers and sailing ships, to the new material mild steel; it also shows that by far the greater number of vessels now building are ships of large dimensions propelled by engine power:

	Mild Steel		Iron		Wood		Total	
	No.	Tons gross	No.	Tons gross	No.	Tons gross	No.	Tons gross
Steam	89	159,751	555	929,921	6	460	650	1,090,132
Sailing	11	16,800	70	120,259	49	4,635	130	141,694
	100	176,551	625	1,050,180	55	5,095	780	1,232,826

If to the improvements already achieved could be added an engine of half the weight of the present steam engine and boilers, and working with only half the present expenditure of fuel, a further addition of 30 per cent. could be made to the cargo of an Atlantic propeller vessel—no longer to be called a steamer—and the balance of advantages in favor of such vessels would be sufficient to restrict the use of sailing craft chiefly to the regattas of this and neighboring ports.

The admirable work on the "British Navy," lately published by Sir Thomas Brassey, the Civil Chief Lord of the Admiralty, shows that the naval department of this country is fully alive to all improvements having regard to the safety as well as to the fighting qualities of Her Majesty's ships of war, and recent experience goes far to prove that although high speed and manœuvering qualities are of the utmost value, the armor plate which appeared to be fast sinking in public favor is not without its value in actual warfare.

(To be continued.)

A SUMMARY OF PROGRESS IN SCIENCE AND INDUSTRY, 1882.

[From the Report of the Secretary, January 17, 1883.]

Like its immediate predecessor, the year 1882 was not characterized by the announcement of any great or revolutionizing discoveries, or industrial processes, but rather by the steady and satisfactory advance in the arts and sciences, and by general industrial activity and business prosperity. I give below a brief summary of the more notable facts and events that appear to be worthy of special mention before the Franklin Institute in recording the progress of the past year.

In constructive engineering there is little to record during the year 1882, save the fact that considerable progress was made towards the completion of the superstructure of the bridge across the East river and upon the tunnel beneath the Hudson. The Channel tunnel scheme has met with a serious set-back, singularly enough, by reason of an agitation based upon political considerations. Concerning the condition of work upon the interoceanic canal at Panama, in the absence of reliable information, nothing can be said. It appears probable, however, that considerable preliminary work has been accomplished. Considerable interest was aroused in the engineering fraternity during the past year, by reason of the investigation by a commission of government engineers, appointed by the Secretary of the Treasury, of a theory of steam boiler explosions with which the name of Mr. D. T. Lawson, of Wellsville, Ohio, is prominently identified. The theory in question is substantially that steam boilers explode by the sudden abstraction (by whatever means) of a considerable volume of steam, which, by relieving the superheated water in the boiler of pressure, causes it to instantly burst into steam; this, meeting with the sudden check offered by the resistance of the confining shell of the boiler, produces a concussive effect upon every square inch of the boiler much greater than the normal steam pressure, and frequently sufficient to cause the boiler to explode with violence.

In several trials by this commission, it was demonstrated that steam boilers could be violently exploded at pressures far below those which they had previously withstood without injury, by simply providing means for the sudden removal of the steam from the steam space. While there are some differences of opinion as to whether the experi-

mental device employed in these trials did not considerably exaggerate the conditions that may be conceived to be brought about in practice, it will be generally conceded that Mr. Lawson has laid the engineering world under obligations by properly formulating and bringing into prominence a real and active factor in the possible causation of steam boiler explosions, which the mechanical world has hitherto ignored. As a safeguard against this danger, Mr. Lawson has proposed an arched perforated diaphragm, fixed horizontally in the boiler near the water-line, and supplied with valves under the control of the engineer. The object of this device is to retard the time of the passage of steam from the water compartment into the steam compartment, and thus prevent instantaneous removal of pressure from the water. I may add in conclusion, that the government commission in its report indorsed the theoretical views of Mr. Lawson, and the efficiency of his system of boiler construction.

Some attention was attracted during the year to the experiment of operating street cars upon the cable system of propulsion which has been going on during the past year in Chicago. This system has been in successful operation for some years in San Francisco, and the Chicago experiment is pronounced to have been so satisfactory that it has been considerably extended. A similar road was also laid down in Philadelphia during the year, and is now about going into operation. It is not at all unlikely that this system may come in time to be generally adopted.

The interest in the subject of electric lighting during the past year continued unabated. The practical availability of the system of arc lights for the lighting of large buildings and streets, may now be considered as fully demonstrated, and the public interest is concentrated upon the adaptability of the several plans employing incandescent lamps, for domestic purposes, to take the place of gas. By far the most important experiment of this nature that has yet been attempted, is that of the Edison system in New York, and which has been in operation over a considerable district, in the lower part of the city named, during the greater part of the year. Thus far, however, it has been impossible to learn from authoritative sources anything respecting the important question of cost of producing the light, upon which the success of the company and the further extension of the system will depend. It would be unjust, in view of the importance of this experiment, to interpret the silence of the company unfavorably, as has been

done in the newspapers, and I shall therefore pass the subject by without further comment.

The present year will doubtless witness the demonstration of the feasibility of domestic lighting, since public announcement has lately been made that an experiment upon the large scale, similar to that of the Edison, is about to be made by the plan of employing secondary batteries, which will be furnished to each building, and will be charged to saturation from a central station during the hours when light is not required, and which will be capable of supplying the maximum number of lights that will be required. The cost of a plant for this system will be very much less than that of the direct supply system, and the current sent to the lamps being quite free from variations of intensity, the difficulty from the breakage of lamps, it is claimed, will be reduced to a minimum.

During the past year secondary batteries upon the Faure system have been applied practically for lighting railway carriages both in England and in this country; and, without implying the necessary failure of other systems, I think it safe to say that the ultimate success of the electric light as a practical competitor of gas will depend largely upon the perfection of the secondary battery.

I had occasion in my last year's summary to characterize the year 1881 (during which nearly 8,000 miles of new railroad were constructed in the United States), as a phenomenal year; but in this respect it must yield the palm to the year just passed, during which the enormous aggregate of not less than 11,000 miles of new road was added to the railway systems of the country. There are evidences, however, that the climax has been reached, and that the present year will show a notable diminution in railway extension.

In the production of iron and coal, the two most prominent indicators of our industrial condition, the figures of the past year will probably be found not to vary materially from those of the year 1881, which, in both these factors, exceeded those of any previous year of our history.

The figures of the production of the precious metals in 1882 show a slight decrease as compared with those of 1881.

The successful establishment of the beet sugar industry in the United States, as demonstrated by the profitable operations of the Alvarado factory in California during the past year, is a subject for congratulation, as being the first promising indication that the difficulties surrounding the domestication of this important industry have been successfully overcome.

The introduction into the United States of the Solvay process for manufacturing soda, commonly known as the ammonia-soda process, is also worthy of special note as an important industrial event. The glucose industry has fully maintained the phenomenal rate of increase that has hitherto distinguished it, and one establishment of really colossal proportions has been erected in Chicago during the past year, and is just now about being put in operation.

The statement has been extensively circulated during the past year, on the alleged authority of Sir Henry Bessemer, that a new process for producing the metal aluminium was being experimented with, giving very promising results, which would enable this metal to be produced at nominal cost. Thus far no details respecting this much-to-be desired process have been made public.

One of the most interesting technical suggestions advanced during the past year, was that of Mr. Mosely before the British Iron and Steel Institute, to do away with the use of gunpowder, or other explosives, in breaking down coal in the mine, and thus avoid the danger of igniting fire-damp, and other dangers and inconveniences attending the present methods. For this purpose Mr. Mosely employs lime, consolidated into cartridges by a hydraulic pressure of 40 tons. By a simple and inexpensive method these cartridges are confined in the bore holes in such a manner that when a quantity of water is forced into contact with them, the combined effect of the steam generated and the expansion of the lime in slaking, the coal is broken clean from the roof in from 10 to 15 minutes. By this method the amount of wastage from small coal, which is ordinarily very considerable, is reduced to a minimum, as nearly all the coal falls in large masses. It completely avoids the danger of igniting fire-damp, and instead of vitiating the atmosphere of the mine, exerts a most grateful influence in purifying it. The method is said to work like a charm, and has already been introduced with much satisfaction in some of the Derbyshire mines in England, and into certain Belgian collieries.

The manner in which the solar heat is maintained has always been a vexed question with physicists and astronomers; all, however, have hitherto agreed that whatever its origin, the solar heat could not be indefinitely maintained, and that the sources of the seemingly exhaustless floods of energy our central orb has been radiating into space for countless ages, must be continually, though imperceptibly, diminishing; that the time must infallibly come—though indefinitely remote

—when the diminished intensity of the solar emanations would no longer suffice to sustain life upon the earth; and that the ultimate fate of our solar system was to be reduced to the condition of an aggregation of dark, cold and lifeless planets with their satellites, circling about a dark and burned-out sun.

This view, it is interesting to note, has been challenged during the past year by Dr. C. W. Siemens. He considers that the interstellar spaces are filled with gaseous matter—hydrogen, hydro-carbons, oxygen, etc.—in a very attenuated condition; that these gases are attracted in enormous quantities towards the polar surfaces of the sun, passing, in their approach to the solar surface, from a condition of extreme tenuity and cold, to that of compression, accompanied with rise of temperature; that, finally, on reaching the photosphere, they burst into flames, giving rise to a great development of heat; and that the products of combustion—aqueous vapor, carbonic oxide and anhydride—yielding to the influence of centrifugal force, will flow towards the solar equator and thence be projected into space. He holds it to be probable now, that solar radiation would step in to return these combustion products back again to their original condition by a process of dissociation carried on at the expense of that portion of the solar energy that is now supposed to be lost to our planetary system by radiation into space. This probability he bases upon experiments by which he has obtained unmistakable evidence of the dissociation of water vapor by the simple action of the solar rays. Upon this interesting and plausible hypothesis, therefore, the rays of our own, and of countless other suns that are traversing space, are made to perpetually renew the supply of fuel required for the maintenance of combustion upon the solar surface.

Though not unknown to physicists, the practical application of the spectroscope as a weather indicator, by the observation of the intensity of the so-called rain band (the absorption spectrum of aqueous vapor), which occupies a portion of the solar spectrum, has of late come to be quite generally known and practiced. Its indications are said to be infallible in enabling one to predict the occurrence or absence of rain, under some circumstances, for a day or two in advance. Rain-band spectroscopes have been constructed by certain opticians, so small that they may be carried in the pocket, but so powerful and true that a glance of two seconds through them suffices to tell an experienced observer the general condition of the whole atmosphere.

In November of the past year occurred the hundredth anniversary

of the first experiments of the Montgolfier brothers, at Avignon, in France, with balloons. The occasion was duly observed by the several European aeronautical societies. The principal interest of this circumstance to us, is the opportunity it affords us of noting how little has actually been accomplished in a century towards perfecting the art of aerial navigation. With the exception of some trifling improvements in the construction of the balloon, and a few questionably successful efforts in directing its course, the art of aerial navigation stands, for practical purposes, where the Montgolfiers and their contemporaries left it. With the perfection of the secondary battery, it is hoped that electric motors may soon be successfully applied to the directions of balloons; but thus far the problem of aerial navigation remains unsolved.

In geology, perhaps the most interesting event of the past year was the announcement by Prof. H. C. Lewis that he had succeeded in tracing the terminal moraine of the great ice sheet, that covered the northern portion of this continent during the glacial period, in Pennsylvania, for a distance of 400 miles across the great divide between the Atlantic and the Gulf of Mexico. The southern limit of the great ice sheet had previously been traced from Cape Cod across Rhode Island, Long Island, New Jersey, New York, Ohio, Indiana, and other States farther West; and Prof. Lewis' discovery fills out an important gap that has hitherto been missing, and completes the line of the moraine.

As the direct outgrowth of Pasteur's classical researches in establishing the germ theory of infectious diseases, we may refer to the announcement made during the past year, of the important discovery by Dr. Koch, of Berlin, of the bachterial or parasitic origin, and consequently the infectiousness of tubercular disease. Dr. Koch's conclusions were based upon a multitude of observations, in the course of which he demonstrated the invariable presence, in tuberculous material, of myriads of minute organisms possessing all the characteristics of bacilli, which he succeeded in identifying, and with which he also succeeded in transmitting tuberculous disease with all its characteristic symptoms to guinea-pigs, rabbits, and cats, by inoculation; and this was successfully done, not only by transferring the tuberculous matter from diseased animals to healthy ones, but by employing the purified bacilli which had been obtained by cultivation and reproduction in a pabulum, extending over a period of six months. Dr. Koch's researches seem to have all the force of demonstration, and his conclusions appear to have met with almost universal acceptance.

Book Notices.

THE ACTUAL LATERAL PRESSURE OF EARTHWORK. By Benjamin Baker, M.Inst.C.E. Reprinted from Minutes Proc. Inst. C.E., London. Van Nostrand's Science Series. Price, 50 cents.

This contribution to the theory of retaining walls is one of the most valuable that has appeared from the fact that it is a compilation of a large number of experiments, and of dearly-bought experience by one who has given the question considerable thought. The long analytical formulæ, so common in treatises on earth pressure, are usually misleading and disappointing. "One authority after another has simply evaded the task of experimental investigation by asuming that some of the elements affecting the stability of earthwork are so uncertain in their operations as to justify their rejection, and have so relieved themselves from further trouble." Mr. Baker has given only empirical inductions from the actual cases he has collected. The one regret we have to express refers to a want of systematic arrangement for better reference, which would have greatly enchanced the practical value of the book.

The conclusions finally arrived at, of course, do not differ much from common custom, but the proper limits which are given of thickness and batir under different conditions will be useful. It was found that the actual lateral thrust of good earthwork was less than ordinary text books would lead a student to infer, and, on the other hand, that by practical examples of dock and other walls, in actual works, a larger factor of satety was required to cover contingencies of various kinds and degrees. A proper discrimination, therefore, between the pressure of good earthwork alone and other conditions would tend sometimes to lessen, at other times to increase, the thickness of walls as ordinarily designated in books.

The paper is illustrated with a large number of cuts, and is followed by a discussion on the conclusions advanced by other eminent English authorities on the subject, who add results of their own experience, either endorsing or modifying those of the author.

Altogether we can, perhaps, nowhere else find such a wealth of facts within the same compass concerning the stability of retaining walls, and the practical engineer will seldom have to search in vain among them for a parallel case to his own. R. H.

American Foundry Practice. Treating of loam, dry sand and green sand moulding, and containing a practical treatise upon the management of cupolas and the melting of iron. By Thomas S. West, practical Iron moulder and Foundry foreman, (fully illustrated) New York, John Wiley & Sons, 15 Astor Place, 1882.

This is a work such as only a practical moulder could write, and just the kind of a work needed by those engaged in the craft.

The subject, a very dry one, would not promise agreeable reading, but the way the author has handled it shows how a very great amount of instruction, even on so uninteresting a subject as moulding in sand, may be rendered pleasing reading matter. There is a vein of humor running through the information conveyed, which cannot help but interest the working moulder, and lead him to peruse its pages, when, if there was nothing beyond the mere information afforded by the subject, he would probably only refer to just such parts as for the moment were wanted.

The whole subject of moulding in green sand, in dry sand and in loam, is well handled, and numerous examples are given of how to mould patterns, selected for their known difficulty, as experienced by the author himself. Making castings with but small parts of patterns and cores without boxes. To be able to make castings from patterns, finished in every detail, is not so very difficult a matter, but to be able to make good, serviceable castings wlth only a trowel, a few pieces of wood, and the foundry floor, shows a master hand worthy of the name of moulder. The author does not go so deep as this, but leads considerably farther in that direction than is generally practiced in the workshops of this country.

The chapters on contraction of castings, and feeding the moulds to prevent it, straining of the moulds, burning on of metal, and mixing and melting of iron, are well mapped out. The work is also interspersed with numerous wood-cuts, showing the manner in which certain work should be performed, making the author's meaning clearer. The illustrations showing improved forms of iron cupolas, air furnaces, foundry ladles, and ingot moulds, etc., are particularly good and valuable to all interested in the manufacture of iron and steel. The book successfully fills a want, and every mechanic would profit by reading it. W. M. H

Papers on Mechanical Subjects. By Sir Joseph Whitworth, Bart. London: E. & F. N. Spon, 1883.

The recent discussion in our mechanical journals of methods and appliances for accurate measurement, which was evoked by the completion of the very ingenious Rogers-Bond Comparator, lends a special interest to the reprint of a number of Sir Joseph Whitworth's writings which have recently been published under the title of "Papers on Mechanical Subjects." Volume I, that is now before us, treats of:— "True Planes, Screw Threads, and Standard Measures." The papers here reproduced, some six in number, were most of them read at different times before various scientific societies, during the period from 1840 to 1881, and they afford an interesting illustration of the persistence with which their author has preached the doctrines of standards and interchange ability. The British "Board of Trade" has recently crowned his labors by adopting his gauges as the final standards to which local authorities may compare any gauges which may be submitted for inspection. It is hoped by this means to establish throughout the workshops of the country an identity in the unit of measurement which will conduce to greater accuracy of workmanship and vastly increase the possibilities of interchangeable manufacturing. The success or failure of this effort will, however, depend largely upon the accuracy of the standards selected; and recent investigations lead us to think that it is by no means certain that Whitworth's gauges are good enough to accomplish all that the Board of Trade expects of them.

This step on the part of the Government is, of course, a triumph for Whitworth, and an acknowledgment for which he has long striven. In the preface to the little book before us, he says: "It is in consequence of this official recognition of the Gauges, which constitutes the last step in the direction of accurate measurement, and the means by which increased simplicity and economy of manufacture have been rendered possible, that I have determined to bring together in a permanent form the papers descriptive of the earlier stages by which this last step has been reached."

It is interesting to note that the preface also deplores with much reason the want of uniformity in sizes and the unnecessary multiplication of sizes in many branches of manufactures, and points out that a great economy in production and improvement in the product would result from the adoption by every manufacturer of the smallest number of patterns and sizes with which the wants of the consumer could be sat-

isfied. As a familiar example of this, the author alludes to candles—an illustration which comes home to every one who has had to whittle down a thirteen-sixteenth inch candle to get it into a three-fourth inch socket, or wrap paper around a small candle to make it stand straight in a stick an eighth of an inch too large. Whitworth says he found in *one* large candle works eleven sizes between six-tenths inch and one inch diameter, all of uncertain size, and none of them bearing any relation to the sockets of candlesticks, while the same range could be obtained with greater convenience by the use of five sizes between the same limits varying from each other by one-tenth of an inch.

The first of the papers is that on Plane Metallic Surfaces, and treats of scraped surface plates, which appear to have been a novelty in 1840 when this paper was read, the usual method then in vogue to attempt to produce true planes being by grinding. The author points out clearly the difference in the results obtainable by the two methods.

The interest attaching to this and the succeeding paper on screw threads, is largely historical, as they enable us to compare to some extent what was considered good practice forty years ago with that usual in the best shops of the present day. We can congratulate ourselves on a vast improvement, but undoubtedly there is still a wide field for further progress in the same direction. When Whitworth originated his screw thread system, he apparently assumed as axioms that it was inherently impossible to make a system that would meet the requirements of all users of screws, and that it was equally impossible to arrive at the proper proportions by deductive reasoning or mathematical analysis. His method was simply to find the average practice, and to do this he made an extensive collection of screw bolts from the principal workshops of England, and observed the average pitch for different diameters, noting particularly one-fourth, one-half, one, and one-and-one-half inches, and deviating from the exact average only when it was necessary to avoid inconvenient fractions. The angle of the thread was likewise determined by adopting fifty-five degrees, the average of the various angles used in different shops. No attempt was made to find a formula that would express the pitch in terms of the diameter. The table thus compiled covered screws from one-thirty-second inch to six inches diameter, while additional tables were made for pipe threads and for screws for watch and instrument makers, covering screws from one-hundredth inch to one-tenth of an inch.

In another paper here reprinted, Whitworth makes a plea for the

introduction in the workshop of a decimal division of the inch, because the convenient and natural binomial division he thinks does not afford a unit sufficiently small to express those differences of size which are necessary in fitting parts of machinery together, and he ridicules justly the use of such loose and dubious terms as "full" and "scant," arguing that a familiarity with the expression of sizes in thousandths or ten-thousandths of an inch would educate the mind to an exact appreciation of differences in size, and would conduce to increased accuracy in workmanship. It would, also, he thinks, enable the workman to put in permanent form the results of his experience and to impart his knowledge to others in precise terms. It is questionable, however, whether the adoption of such a system to the exclusion of that now in use would prove profitable. It would be highly impracticable to discard the usual shop and mercantile sizes of bar-iron for example, and yet to express eighths and sixteenths in three decimals would be perhaps, tedious and awkward. It certainly seems easier and quicker to say "three-eighths drill," than to speak of the same tool as a "drill of three hundred and seventy-five thousandths diameter." On the other hand, to introduce a new system of shop sizes founded upon the decimal division of the inch would involve an outlay for changes in gauges, reamers, drills, mandrils etc., that would practically be prohibitory.

In fact, the continued use of the ordinary nomenclature does not seem incompatible with great accuracy of expression, if we restrict the use of the decimals to expressing those sizes which cannot be exactly given in terms of the binomial division of the inch.

Whitworth also alludes to the difficulty of keeping shop tools up to size and enlarges upon the importance of having fixed standards with which to compare them. In his paper "On Measurement," he describes in general terms his well-known Micrometer Measuring Machine, with which he *claims* to read differences of size as small as one-millionth of an inch, by use of a "gravity piece," which will fall out if the screw is moved an amount which, by calculation of the gearing and screw would appear to be this minute quantity. Among the decimal tables given in this book is the Whitworth Wire Gauge, which its inventor offers as a substitute for the Birmingham and other gauges known to the trade. He proposes to call wire or metal plates by numbers, which shall mean their thickness expressed in thousandths of an inch; thus No. 12 would be twelve-thousandths inch thick, etc. Simple as this appears, it has not been widely adopted, and it is alleged against it, by

some, that while it entirely revolutionizes the present systems of numbering, it does not meet the requirements of the manufacturer. Other gauges give the smallest numbers to the greatest thicknesses, and then as each successive "pass" diminishes the thickness, the resulting product is called by a higher number. In these days of cheap micrometer callipers, it is not apparent to the mass of mankind why a simple expression of size, thickness, or diameter, in decimal parts of the inch would not answer all purposes of manufacture and sale with better results than can be obtained by fitting plates or wires into notches in a gauge. Unless indeed the use of a larger number of figures is found to be too cumbersome.

Whitworth, in these papers, tacitly assumes a degree of mechanical exactness for gauges of his manufacture, which, although it has been very generally conceded, may yet be proved not quite deserved, and it is confidently predicted that gauges will soon be manufactured in this country with an accuracy superior to that of Whitworth's celebrated make. Be this as it may, however, Whitworth has been so long regarded as a pre-eminent authority in mechanical matters that we cannot but read with respectful attention whatever he has written on subjects which have absorbed so much of the thought of his long life. We are gratified that these interesting papers have been put into accessible form, and hope that this volume will be followed by others from the same able pen. C. S., Jr.

Lockwood's Directory of the Paper, Stationery, and Printing Trades. Containing a List of Paper Manufacturers in the United States and Canada, and Paper and Paper Stock Dealers in the Principal Cities. New York, Howard Lockwood, Publisher, 1882; price $2.00.

The above partial title sufficiently describes the general scope of this octavo volume of about 450 pages, which must prove very useful to parties engaged in manufacturing paper or dealing therein, and in books and stationery. It has a list of the wholesale and retail booksellers and stationers throughout the United States and Canada, and a "complete list" of book, newspaper, job, and lithographic printers. The directory, which is conveniently arranged by States, cities, etc., contains 23,000 names, and has also the advantage of a very copious index. The whole arrangement—which includes good paper and typography—is excellent and creditable to the publisher. N.

Twinkling and Scintillation.—Karl Exner attributes the colored scintillation of stars to the combined influence of the regular dispersion of the rays and the irregular refractions in the atmosphere. The scintillation when near the horizon is colored, but uncolored when near the zenith.—*Wied. Ann.*, No. 10, 1882. C.

Insulite.—A new electrical insulator is described by *L'Industrie Belge*, to which the name of insulite has been given. The materials which enter into its composition are wood, sawdust, cotton rags, papier maché, and other fibrous substances. By a special treatment the materials are rendered proof against water and acids, and easy to work and shape in all forms. It can be employed in batteries, or as an insulator for telegraphic, telephonic, and illuminating wires. Its price is much less than that of ebonite or gutta percha.—*Chron. Industr.*, No. 37. C.

Caustic Lime in Coal Mining.—In answering some objections that have been urged against the efficiency of lime in coal mining, Paget Mosley says that he has found it to answer every purpose in respect of which gunpowder or wedging have been hitherto used. In the Shipley collieries, where the lime process has been in constant operation for many months, it is regularly applied to one of the hardest seams in the Midland coal-field, the toughest part of which is that next the roof, and this portion could never be got by wedging in the ordinary way, but had subsequently to be hacked down into slack. By the lime process, however, the coal is parted clean from the roof along the entire face operated on.—*Nature*, xxvi, 365. C.

Fire-proof Paint.—Vildé and Schambeck make a varnish of 20 parts of powdered glass, 20 parts porcelain, 20 parts powdered stone of any kind, 10 parts calcined lime, 30 parts soluble soda glass. The powders are made as fine as possible and sifted, and then thoroughly incorporated with the soluble glass, thus producing a syrupy mass, which can be employed as a varnish or mixed with colors for painting. The proportions of the solid ingredients may be varied at pleasure, but it is generally best to keep the indicated portion of lime. Silicate of potash may be substituted for the silicate of soda if desired. The first coating soon hardens and a second coat may be applied from six to twelve hours afterwards. Two coats are sufficient. The varnish may be employed as a preservative against rust.—*Chron. Industr.*, No. 39. C.

Evaporation of Quicksilver in a Vacuum.—H. Hertz has made some investigations of the evaporation of liquids, especially mercury, in a vacuum. The chief interest of his results is connected with the pressure of the vapor at the ordinary temperature of the air. According to his experiments, the pressure amounts to less than a thousandth of a millimetre (one-twenty-five thousandth of an inch). The insignificance of this pressure, rather than any special peculiarity of the quicksilver itself, must be the reason for the imperceptible influence which the quicksilver vapor, in Geissler tubes, produces upon the discharges.—*Wied. Ann.*, No. 10, 1882. C.

Use of Glycerine in Silvering Glass.—Some substances possess the property of reducing silver salts and thus producing an adhesive layer of brilliant metallic silver on the walls of the tubes which are used in the experiment, but unfortunately the mirror which is thus obtained is not perfect. Prof. Palmieri had the happy thought of employing glycerine, which seems likely to open a new future to the art of silvering. When glycerine is added to an ammoniacal solution of nitrate of silver, after a while the liquid becomes brown, then it deposits a black substance and becomes limpid and colorless. If the mixture is re-heated it takes a gradually deepening brownish hue; at the boiling temperature it becomes black and leaves upon the tube a metallic deposit of a steel gray color. If some drops of caustic potash are added to the mixture of glycerine and ammoniacal solution, after a short time there is a reduction of silver, which forms a very brilliant precipitate. If ether is added to this last mixture a metallic ring is formed almost instantly and in a few seconds the reduction is completed through the whole mass. The agitation of the liquid renders the reduction more uniform. If alcohol is substituted for the ether, the reduction is a little more rapid and the mirror very brilliant. The action of light and heat modify this reaction. Darkness favors the brilliancy and adhesiveness of the coating. The best result is obtained with caustic potash, when the mixture is between 60° and 70° (140° and 158° F.) with potash and ether, between 30° and 35° (86° and 95° F.) with potash and alcohol, between 40° and 45° (104° and 113°). The reaction is complete in eight or ten minutes. Prof. Palmieri promises a second note in which he will give the proportions of the different liquids which are necessary in order to yield the best result. —*Les Mondes*, Sep. 23, 1882. C.

Magnetic Observation during the Total Eclipse of May 17, 1882.—There is still some uncertainty as to the true cause of the abnormal magnetic variation, which is generally observed during solar eclipses. Is it a direct magnetic action of the two bodies which are in conjunction, or is it a simple effect of the variation of temperature and of atmospheric humidity, which ordinarily accompany the phenomenon? The observations at Zi-Ka-Wei, China, during the eclipse of May 17, 1882, seem to corroborate the second hypothesis and to remove all probability from the first. Marc Dechevrens, the director of the Zi-Ka-Wei observatory, reports his own observations upon that occasion, and confirms his conclusions by comparisons with observations upon the eclipses of 1868, at Célèbes, and 1878, at Denver. He finds additional confirmation from the disappointment of Dr. Little, an amateur astronomer of Shanghai, who was unable to make the observations which he expected on account of the cloudy sky. [These conclusions are confirmatory of the views recorded by Chase, in 1864. *Proc. Am. Phil. Soc.*, vol. ix; *Trans. Am. Phil. Soc.*, vol. xiii.] *L'Astronomie*, i, 270, C.

Electric Properties of Flames.—In 1827, Pouillet advanced the idea that the electricity of flame is due to the fact of combustion and, therefore, probably analagous to the electrification observed by Volta, on placing a burning coal or pastille upon the top of an electroscope. In 1854, Matteucci explained the phenomenon by supposing that the flame acted as an electrolyte upon the two metallic electrodes, in the same way as the acid between the two plates of a voltaic pile. This view accords with one which had been previously advanced by Hankel. Buff sought the explanation of the phenomenon in the thermoelectric difference of the two electrodes. Sir William Grove has shown that on bending a platinum wire, so that one of its ends touches the summit and the other, the base of the flame, an electric current flows through the wire. At first glance this phenomenon seems to agree with Hankel's observation, that a flame is polarized longitudinally, but it is probable that all these explanations should be modified by considerations of the electric influence exercised by the envelope of heated air which surrounds the flame. Elster and Geitel have experimented with Thomson's quadrant electrometer and have found that the flame is not by itself a source of electricity; they regard the production of electricity as a thermo-electric phenomenon.—*L'Electricien*, Oct. 15, 1882. C.

Liquefaction of Ozone.—Hautfeuille and Chappuis compressed a mixture of oxygen and ozone, in Cailletet's apparatus, under a pressure of 125 atmospheres and at a temperature which was probably below —100° (—148°F.). When operating with a gas not containing more than 10 per cent of ozone, the blue color was very marked in all the chilled portion of the capillary tube. The experimenters were unable to determine positively whether this coloring was due to a mixed liquid of ozone and oxygen, or to a thin layer of liquid ozone on the inner walls of the capillary tube. When the ozone is liquefied in the capillary tube, it preserves its condition for a considerable time, even under atmospheric pressure, so that it can be examined and even withdrawn for a few moments from the chilled tube.—*Comptes Rendus*, xciv., 1249. C.

Franklin Institute.

Hall of the Institute, January 17, 1883.

The annual meeting of the Institute was held this evening at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

Present 86 members and 15 visitors.

The minutes of the last stated meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the meeting held January 10th, 14 persons had been elected members. He likewise presented the following resolutions passed by the Board at the meeting above named, viz.:

Resolved, 1. That the Board of Managers of the Franklin Institute has heard with great regret the proposition to transfer the Coast and Geodetic Survey of the United States from the Department of the Treasury to the Navy Department.

Resolved, 2. That a committee be appointed to prepare a remonstrance to Congress against the proposed transfer, and to present said remonstrance to the next meeting of the Institute for its action.

Resolved, 3. That the committee shall consist of three; and that the President be added thereto.

Upon which the President named the following to serve on the committee, viz.: William Sellers, William Helme, Dr. Persifor Frazer, and William P. Tatham.

On motion of Mr. Wm. Sellers, the regular order of business was suspended in order to consider the report of the committee, which was as follows:

The committee appointed under a resolution of the Board of Managers to prepare a petition and remonstrance to Congress, to be submitted to the Institute for its action, respectfully presents the following memorial:

To the Senate and the House of Representatives of the United States, Washington, D. C.:

Petition and remonstrance of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully represent—

That your petitioners have heard with great apprehension of the proposal to transfer the Coast and Geodetic Survey of the United States from the Treasury Department to the Navy Department, and would respectfully remonstrate against it for the following reasons:

1st. That the Survey was under the control of the Navy Department from 1819 to 1832, and that the results obtained were condemned by the then Secretary of the Navy, Mr. Southard, as unsatisfactory.

2d. That the existing organization of the Coast Survey, adopted after wise consideration, has produced magnificent results, with economy, rapidity and accuracy.

3d. That, in the words of the report of our committee, made in February, 1849, "the labors of the Survey ought to be (as they now are) divided among the Civil, Military and Naval talent of the country, in order to secure to each of these departments that knowledge of its processes and determinations which are equally required of them all."

4th. That it would be as unwise to put the Army officers under the Secretary of the Navy as to put the Naval officers under the Secretary of War, and that either arrangement would engender jealousies and suspicions which the present organization avoids.

5th. That the service being a peaceable one, the civil element should constitute the chief and permanent part of the organization, otherwise the occurrence of war, by calling the military branches to more congenial duties, would not only disorganize the service, but, for the time, would bring its operations to a close. To guard against such a misfortune and to insure that the Civil element should predominate, the Survey should remain under the Secretary of the Treasury, whose

department represents the interests of commerce, which it is the chief end of the Survey to subserve.

6th. That when, in 1848 to 1850, a similar suggestion was pending, the proposition fell of its own weight under the light of discussion (see "Congressional Globe," vol. 23), although chiefly supported by a reason which has now lost its force, namely, that the whole *object* of the Survey then, was hydrographical, the Geodetic branch of it being merely to supply a base of landmarks to connect and support the hydrography; whereas, now, the object of the Survey is to cover the territory of the United States from ocean to ocean, so as to connect both coasts, and therefore the peculiar service of the Navy bears a much smaller proportion to the whole.

7th. That it does not appear that the Treasury Department is dissatisfied with the existing arrangement for the service, nor that the officers of the Survey are discontented with their present head, nor that the existing organization has failed in any way to justify the wisdom of its founders.

Your petitioners therefore pray that your honorable body will maintain a system which has worked well for nearly fifty years, and not return to one which experience has condemned.

The Committee recommends the adoption of the following resolution:

Resolved, That this, the foregoing memorial shall be signed by the President, and that the Secretary shall attach the seal of the Institute thereto, and that it be duly forwarded.

Wm. Sellers,
Wm. Helme,
W. P. Tatham,
Persifor Frazer.

The report as read was unanimously adopted.

The Actuary then presented the following:

Annual Report of the Board of Managers.

The Board of Managers of the Franklin Institute of Pennsylvania, for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute during the year 1882, viz.:

Members.—During the year 131 new members have been added and 32 have resigned.

Treasurer's Report.—The following is a condensed summary of the report of the Treasurer for the year ending December 31, 1882:

Receipts.

Balance on hand January 1, 1882, .	$1,325 64	
Cash received from investments sold out, .	19,560 00	
Current receipts from all other sources, . .	14,789 00	
		$35,674 64

Payments.

Amounts re-invested, . . .	$18,673 33	
All other current payments, . .	15,069 66	
Balance on hand Dec. 31, 1882, . .	1,931 63	
		35,674 64
Showing decrease of money invested, .	$886 67	
Increase of cash balance, . . .	606 01	
Balance the wrong way, ...		280 66

Library.—The average yearly increase in the money value of the Library, which was estimated in the last annual report of the Board at $2,000, has been fully maintained during the past year. Over 800 bound volumes were added, and a number of important serial publications were acquired or completed. The Board of Managers refers to the increasing importance of the Library with much gratification. The necessity, however, of additional room for the proper arrangement of the books, was felt more urgently than ever during the last year, and must continue to increase. The Board of Managers cannot pass this subject without alluding to the fact that the destruction by fire of any considerable portion of the Library, placed as it is in a building not fire-proof, would inflict great and perhaps irreparable loss upon the Institute and the community, since many of the volumes could not be replaced and cannot be found elsewhere.

Journal.—The JOURNAL, conducted as heretofore, by the Committee on Publication, with the assistance of the Secretary, was more than self-supporting during the past year. The Committee found it necessary to increase the edition printed, and the analysis of its report shows that the business of the JOURNAL has never been so large.

A general index to the JOURNAL is in preparation, and the Board feels assured that its value as a record of past progress for 59 years, will be greatly increased thereby.

Lectures.—At the beginning of the year, Prof. S. T. Skidmore completed a course of six illustrated lectures on "Mechanics," followed in the order named below, by Mr. Henry Trimble, with eight illustrated lectures on "Modern Chemistry;" Prof. M. B. Snyder, with four on "Astronomy;" Mr. Reuben Haines with four on "Applied Chemistry;" Mr. A. E. Outerbridge, Jr., with four on "Physics;" and Mr. D. S. Holman with one on "The Microscope and its Teachings." A number of lectures instructive and entertaining were also delivered under the auspices of the Phonetic Section.

The Autumn Course was opened by a course of four lectures by Prof. F. B. Maury, of the U. S. Signal Service, on "Meteorology," who was followed in the order named, by the following: Mr. Lorin Blodget, four lectures on the "Science of Statistics;" Prof. William H. Greene, four on "Explosives;" Mr. N. H. Edgerton, three on "Dynamo-Electricity and its Application to Industrial Uses;" and one illustrated "Christmas Lecture" by Mr. D. S. Holman. These lectures have been well attended. The Professors who were elected in 1881 have been of material help to the Committee in giving aid and advice in arranging the lecture courses.

The Committee on Instruction, with the approval of the Board, decided to continue the policy of issuing complimentary tickets to members for distribution to friends, which has been found to give general satisfaction. As noted in the annual report of last year, this arrangement makes the lectures practically free to the public.

Drawing School.—The Drawing School, under the able direction of Mr. William H. Thorne, has been very successful during the past year, and the results are highly gratifying. The attendance increased to such an extent as to require the division of the students into seven classes instead of four, as hitherto. The increase is shown by this statement: The number of pupils in 1882 was 332, as compared with 229 in 1881.

The accommodations not being sufficient for all these classes on the same evening, it became necessary to divide them, accommodating a portion on two evenings and the others on two alternate evenings.

Special attention has been paid by the Director and his assistants to bringing the school under a general system, whereby the students are classified and promoted according to their progress. This plan is found to favor both the improvement of the pupil and the efficiency of the teacher.

The instruction in drawing given by the Institute is in harmony with the practice of the shops, and our students upon graduation are fully qualified to use, interpret, and execute working drawings without having anything to learn or unlearn.

The Board commends the drawing school to the Institute as deserving of hearty support.

Sections.—During the past year an Electrical Section was established, which promises to become useful in promoting the interest of the Institute in this important branch of science. The Chemical Section has fully maintained the expectations formed of it, several useful and important papers having been read and discussed at its meetings and published in the JOURNAL. The interest in the Phonetic Section during the past year continued unabated.

Exhibitions.—The Committee having charge of this subject, conscious of the generally expressed desire that an exhibition should be held during the past year, gave the question careful consideration, and was brought to the conclusion respecting it, that it was inexpedient to hold a general exhibition, for the reasons, that there was no suitable building within reach available for the purpose, and that the condition of the finances of the Institute did not warrant the risk of erecting a special building for the purpose.

The suggestion has been made that a special exhibition, devoted to electricity and its applications in the arts, may be held during the present year, should such be the wish of the Institute at large.

The crowded condition of every branch of the Institute, which has been referred to in several previous reports of your Board of Managers, has continued to make itself felt as a serious inconvenience. After appropriating the rooms formerly devoted to the Models and Collection of Minerals, the rooms for the accommodation of the remaining departments, namely, the Library, the Lecture Room, and the Drawing School, are now so over-crowded as to tax to the utmost the ingenuity of the Committee in charge to make provision for the accomdation of books and students.

The necessity for new and enlarged accommodations, which was referred to last year, has come to be imperative.

To meet this necessity, the Board of Managers will, during the present year, make a renewed effort to obtain subscriptions to the building fund sufficient to insure the erection of a new and suitable building. The

members of the Institute are earnestly requested to aid the Committee having this work in charge, by every means in their power.

By order of the Board, WILLIAM P. TATHAM, *President.*

The Chairman of the Committee on Library presented in behalf of the Committee the following report, which was adopted without dissent, viz.:

The Committee on the Library respectfully reports—

The total number of bound volumes added by purchase to the Library during the past year was 262. Of these 158 volumes were purchased by the B. H. Moore Fund.

The number of unbound volumes added by purchase was 113; pamphlets, 13.

Donations were received of

Bound volumes, . .	302
Unbound volumes, . .	160
Pamphlets, ...	192

making the total of 564 bound, 273 unbound volumes, and 205 pamphlets added to the Library during the year 1882.

Binding.—244 volumes have been bound during the past year.

The total number of bound volumes in the Library, December 30, 1882, was 16,776.

Serial Publications.—Five of the most important serials in the Library have been completed, viz.:

"Armengaud's Publication Industrielle."

"Journal of the Royal Geographical Society."

"Wagner's Jahresbericht."

"Nouvelle Annales de la Construction."

"Revue Générale de l'Architecture."

The Committee has directed the completion of the "Philosophical Magazine" and "Brewster's Journal," which forms a part of this serial; also, the reports of the Pennsylvania Railroad Company, and the proceedings of the "American Railway Master-Mechanics' Association."

Duplicates.—88 volumes have been disposed of during the year, at an average of $1.00 per volume.

Exchanges received for the JOURNAL OF THE INSTITUTE number 208.

Number of volumes taken out by members during the year, 2000.

CHARLES BULLOCK, *Chairman.*

Philadelphia, January 16, 1883.

The Trustee of the Pennsylvania Museum and School of Industrial Art presented the following report which was received and adopted, viz.:

PHILADELPHIA, January 17, 1883.

To the President and Members of the Institute.

Your Trustee in the Pennsylvania Museum and School of Industrial Art, at the close of another year, has the honor to report, that never in the history of the Museum has there been so gratifying an attendance as that for 1882, more than one hundred and fifty-nine thousand visitors having been within its walls, a very considerable increase over the previous year. Whatever a few people may think of the wisdom of establishing such an institution in our city, and its educational value, there can be no doubt of its popularity with the masses and the great interest they take in its collections.

The inventory of the Museum has been completed and a slip catalogue designates the exact location of any object. Quite a number of very interesting things have been loaned to the Museum, some of them of very great value, while Mrs. Bloomfield Moore continues her gifts to the collection in honor of her husband, and the room containing them is one of the most attractive features of the exhibition.

It is part of the plans of the Trustees to store a portion of the less interesting objects of the Museum in the basement of the building, and to use the room thus gained for additional cases, and to have in the spring, lectures delivered on art subjects; the running of frequent Park trains having rendered attendance thereat very easy and at trifling expense to visitors. The plan has been tried with marked success at the Horticultural building, in the Park, and the course of lectures on botany, delivered under the auspices of the American Philosophical Society, has been well attended.

The Industrial Art School, which is so important a part of the work of the Museum, has been carried on at 1709 Chestnut street, and the attendance at night has been all the rooms would accommodate. About ninety pupils have received very thorough instruction from their Principal, Mr. L. W. Miller, and his able assistant in drawing—the foundation of all art,—painting and modelling. The Committee in charge of the School has aimed in the progressive three years' course not only to exalt the standard of instruction, but to make it as thorough as possible in the various constructive and decorative arts,

that its diploma might mean something, as it could only be attained by ability and hard work. The Chairman of the Committee on Instruction, Mr. Frederick Graff, has constantly urged this, and he has been ably seconded by Mr. Miller, who has labored unceasingly, and whose heart has been in the work.

The few graduates of the School have not had the slightest difficulty in getting remunerative positions, showing the need of such a School, especially as a training one for teachers, and the Trustees are unanimous in thinking that when the prospect is so bright, the want of funds should not limit the usefulness of the Museum and School. Some progress has been made to a suitable endowment. About $47,000 have been contributed, a considerable portion given with the condition that fifty thousand shall be raised, and as the income is much wanted to carry on the School, all interested in art education and the industrial prosperity of our city, should see that it is speedily done.

ISAAC NORRIS, M. D.

The Secretary, on behalf of the Chairman of the Committee on Science and the Arts, reported that the Committee had recommended the award of the John Scott Legacy Premium and Medal, to the following:

To Henry Ashford, of Philadelphia, for his "Apparatus for Attaching and Detaching Boats."

To D. K. Miller, of Philadelphia, for his "Self-Locking Padlock."

And to B. H. Kemble, of Philadelphia, for his "Improvement in Vehicle Axles and Boxes."

He reported that the above recommendations had been duly advertised in the JOURNAL for the period of three months, in accordance with the Committee's regulations, and that no objections thereto had been received.

The above recommendations were thereupon taken up and voted upon separately, being in each case approved without dissent.

The tellers of the annual election held this day, between the hours of 4 and 8 P. M., made their report, whereupon the President announced the following as the result, viz.:

President (to serve one year), William P. Tatham.

Vice President (to serve three years), Frederick Graff.

Secretary (to serve one year), William H. Wahl.

Treasurer (to serve one year), Samuel Sartain.

Managers (to serve three years), E. J. Houston, William H. Thorne, Persifor Frazer, Enoch Lewis, William Helme, Charles H. Banes, Frederick Fraley, and John J. Weaver.

Auditor (to serve three years), William A. Cheyney.

On motion of Mr. Burk, a vote of thanks to the tellers for their services was unanimously adopted.

A ballot was thereupon taken for the election of a Trustee of the Pennsylvania Museum and School of Industrial Art, which resulted in the choice of William H. Wahl.

Mr. C. John Hexamer then read a paper on "Dust Explosions in Breweries," which was illustrated by means of a number of lantern views. The paper appears in the JOURNAL for February.

Mr. Robt. Grimshaw gave a summary of the results he had obtained in determining the influence of "Pulley Diameter on the Driving Power of Belts." Mr. Grimshaw illustrated his subject graphically, and claimed from a comparison of a large number of experiments, to be warranted in announcing results at variance from those of Morin and others. The paper has been referred for publication.

Dr. Constantine Fahlberg, by invitation, gave an account of a new sweet substance which had been discovered in the course of some investigations upon coal tar derivatives. The speaker described the process of producing the new body, and exhibited specimens of it and its salts. He defined it to be benzoic sulphinide (or anhydrosulphaminebenzoic acid). Its most distinguishing characteristic is its intense sweetness, being much sweeter than cane sugar. An abstract of Dr. Fahlberg's remarks will appear in the JOURNAL.

The Secretary, in his report, gave a review of scientific and industrial progress during the year 1882, (see page 135) and a description of the following inventions:

A "Revolution Counter," made by the Crosby Steam Gauge & Valve Co , Boston. This registers on a ratchet-toothed graduated dial-plate the number of strokes of a cross-head or any other reciprocating piece of machinery. It is especially intended for use with the steam-engine indicator on locomotives and other very high-speed engines, where the ordinary devices would either break or fail to record all the strokes.

A "Substitute for Turn Tables," designed by F. Lawrence, of Philadelphia. The carriage is intended to carry ladles of melted iron, which must be carried quickly and without spilling. Instead of a turn table a very short curve may be used, and a short curved length of supple-

mental central rail is used, slightly above the level of the two regular rails. Both wheels are rigid on each axle, and there is no swivel to either axle. But there is a central "fifth wheel" between the two main axles, and this swivels on a vertical pivot, and as it engages the central supplemental rail at the turn, the front wheels on the fore axle are raised clear from the regular rails and the truck runs on three wheels, rounding the sharpest curves with ease.

"Cam Lever Saw Set," by C. E. Grandy, Lyndonville, Vt. This device is for bending the teeth of large circular saws alternately to right and left, to give "set" or clearance. It is important that this bending be exactly equal on all the teeth, and shall be done so as not to crack the plate. Mr. Grandy uses a lever and cam, and can draw the thickest plate any desired amount without cracking the bases of the teeth.

The "Gas Machine" of the Peerless Gas Manufacturing Company, of 1411 Vine street, Philadelphia. This is an automatic machine, as distinguished from the carburetting machines, in that it dispenses with the use of springs, weights, etc., in operating it. The gasoline used is first converted into vapor by a small gas jet, and a known quantity of this vapor is then mixed with a definite and predetermined quantity of air. It is claimed that this machine produces gas of a uniform quality at all times. The liquid gasoline to supply the gas, is automatically pumped to the machine in small quantities as required.

Wells' "Unbreakable Lamps and Oilers," offered for exhibition by Messrs. Paine, Diehl & Co. These lamps, etc., are made of cast metal and are practically unbreakable.

Under new business, Mr. W. J. Gregory, seconded by Mr. G. M. Eldridge, moved the following:

WHEREAS, It seems fit that a mark be placed on the John Scott Legacy Medals, awarded on the recommendation of the Franklin Institute, to distinguish them from those awarded by other means; therefore be it

Resolved, By the Franklin Institute, that the form of inscription on the reverse of the John Scott Medals, awarded upon recommendation of this Institute, shall be as follows: "To A. B., for his ——— on the recommendation of the Franklin Institute."

The resolution was adopted. Adjourned.

WILLIAM H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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BRIDGE INSPECTION.

By W. S. THOMPSON.

[A paper read before the Engineers' Society of Western Pennsylvania, December 19, 1882.]

I have been asked by members of this society to give them some of the results of my experience as an inspector of bridge material. To oblige them I offer this paper, otherwise I would not have trespassed upon your time, for so much has been written upon every department of bridge building and in every style, that I very much doubt my ability to say anything that is new on the subject.

For convenience I will divide the paper into the following heads: Inspectors, their duties, etc.; Drawings; Tests.

INSPECTORS.

Every shop that buys any article, on receiving it, gives it to some one to examine to see if it is of the proper material, size and quality. This person, it is clear, must have a knowledge of what this article should be and what deviations are allowable from the order for it. You will reply, of course, he must have such knowledge to be able to decide whether the article is suitable. Perhaps so, but I will venture to say, that if you made such an assertion to the foreman or manager of a bridge shop, he would tell you it might be so in a general way, but that it was not always the case in the appointment of those who

are to look after the inspection of bridge material during manufacture. All of them, at least those of the eight or ten shops I have visited recently, as well as some inspectors of my acquaintance, could cite you cases of inspectors who had little or no knowledge of their duties and a very indistinct idea of any sort of manufacture.

What are the requirements for an inspector? As he must decide questions, to solve which require a knowledge more or less great, of strains, designing, drawing, materials and shop work, it is plain he should be familiar with each of these subjects, particularly the last three, as the first two are generally looked after by his employer. His duties bring him in contact with men of all classes, so I may add that he should have some knowledge of business.

Next, what are his duties? He is appointed by his employer to see for him that an agreement is fairly carried out, neither for the purpose of showing his (inspector's) knowledge and authority, nor for the purpose of annoying and delaying the contractor, on the contrary, he should rather assist him if an opportunity offered itself. I do not mean that he is to consider himself in any way an employé of the contractor, but occasions sometimes arise where some such exertion on his part as can reasonably be asked for, will hasten the completion of his employer's work. In such cases it seems to me to be his duty to make that exertion.

At times there will be instances where there is an honest difference of opinion between the inspector and the contractor. Then the former must hear what the latter has to say, but make up his own mind as to what is right, and to hold to that opinion.

Should he think any question that may arise too important for him to decide, he should refer it immediately to his employer and not vascillate nor delay, for by acting in this way he will weary and annoy every one and possibly stop his work.

While any of his work is being done he should make it his duty to be at the shop during the usual office hours, unless he wishes others to decide for him such questions as may arise during his absence. Of course it is not necessary for him to ask permission from the shop authorities when he wishes to be absent, but it is just as well to let them know when and how long he intends to be absent, even if it is only for an afternoon. If nothing else, this is at least a courtesy, and I do not think courtesy is disliked by any one.

The shop is always to supply him with the necessary labor for

handling work. So far as my experience goes, there is never any difficulty about this matter, provided he will be reasonable, except that there are times when the labor cannot be given at the moment it is wanted, the exigencies of the shop not always permitting of it; but, as a rule, I have found that the superintendents and foremen were always willing to help an inspector in every way, as long as the latter was not all for himself and thought of no one else. The shop has to pay for the labor they give him, therefore it is only proper that he should, as much as possible, arrange his work and his time for doing it in a way that will put the shop to as little expense as possible.

He should avoid being distrustful of every one. If he has cause to believe that people are dealing unfairly with him, there are many ways of correcting the matter, or, at least, of relieving himself of the responsibility resulting from such practices.

I have been asked what errors an inspector should look for, etc. It is difficult to answer general questions in a definite manner, but the following may be answer to some I have had asked: Inspection can be superficial or it can be minute, or somewhere between the two. As an instance I may cite the following: An inspector had some 200 pieces about 15′ long and weighing 800 lbs. each to examine. He had to make at least four careful measurements on each piece before he could say they were correct. To do this took him about two hours a day for some four or five weeks. Another inspector went over that same lot, and gave it what he called a thorough inspection; the time he devoted to it, all told, was not over twenty minutes.

In examining work it is hardly possible to say what one thing to look for. Properly speaking, however, and inspector should expect to find everything exactly as it ought to be. With many inspectors riveting is the only matter that is looked after, but there are also, and of equal importance, the size and quality of the material of the different parts; the straightness of the finished piece; the accuracy of the work done upon it, such, for instance, as the size and position of the pin or other holes, or slots, and how these will compare with the other parts with which they are to fit. To sum up in a few words, he must see that the work in all essentials is exactly what the drawing calls for; also, that the material and the work done on it is of the quality called for, for any or all of these may be wrong. Now, he can examine one piece for all these requirements; he can examine all pieces for one thing, as, say riveting; he can see that each piece is correct in every

detail; or, as I have seen done, he may be able to cast a glance over a lot of work and say whether it is right or wrong. Of how this was done I am ignorant, but of one thing I am sure, the opinion as to its condition was not worth much.

There are times when some points in examination may be omitted; judgment and experience must decide when this can be done, but there should be no mere trusting to luck.

The manufacturer is most undoubtedly reponsible for all these things. Inspection does not relieve him from responsibility, nor does his responsibility relieve the inspector. The latter's employer, and the manufacturer also, provided the inspector is competent, think the matter is of so much importance that it is well to have some one to see that the agreement is fairly carried out.

It might not be amiss for the inspector to remember "that he has a reputation to sustain," and that if he is careless, others will likely be so too; also, that in the oft-quoted Tay disaster there was a strong presumptive evidence that the inspectors had neglected their duties, or were ignorant of them.

What allowance can be made in the way of deviation from drawings? For definite answers special cases would here also have to be cited, but generally the following may be made: As to size, shape irons are generally accepted if they are not more than 3 per cent. light. Rods, flat bars, and plates are more easily rolled to a size, therefore they are seldom accepted if not up to that size, though under special circumstances if the light pieces are but comparatively a small proportion of the whole number, the above percentage may be allowed.

Riveted members should be perfectly straight except top chords and inclined posts, which may perhaps be better for having a slight camber, but I often find it necessary to accept posts say 30′ long out of line by $\frac{1}{4}''$. Some few men work closer than this, and it must be acknowledged it is a very vital point. I inspected the material for a very large bridge, every riveted member of which, except one, was perfectly straight; and the error in that one was, if I recollect right, $\frac{1}{4}''$ in 35′.

Punching is not always accurate. If it is not out more than $\frac{1}{4}''$ in 20′ or 30′ it is considered tolerably good work. In the case of angles used as brackets, if, after being riveted on, they are within $\frac{1}{4}''$ of position, it is considered correct. This is usually near enough.

When work of the above kind must be more exact, it should be so

stated, as it calls for an extra class of work. In the width of chords, *i. e.*, the distance apart of side plates or channels, it is usually considered very fair work when they are within 1–16″ of the distance called for, though they must be nearer than this when the side plates are thin, say ¼″.

Top chords and posts should never have their pin holes bored less than the distance apart called for. 1-32″ excess in former and 1-16″ in latter will never do harm, except in some few special designs. Bottom chord and tie bars should, if they vary at all, be less than the length called for. 1-32″ error in these will not be at all serious, provided all the bars are bored to exactly the same length. Struts if bored within 1-16″ are near enough. Shop foremen generally follow the above rules.

In making eye-bars, the smith is allowed ⅜″ over or under length from out to out. In thickness of head he is allowed 1-32″ under or 1-16″ over required thickness, which he sometimes exceeds, but nothing is allowed at the neck, as this is apt to be the weakest part of the bar. In making lateral or other similar rods he is allowed to vary ½″ either way from required length. Other parts must be made closer than this, but smiths rarely forge very closely.

Pins should never be taken if shorter than called for unless their lengths are calculated for washers, and they should be examined closely to see if they are of uniform diameter and not gouged out at the corners or ends.

Rollers may vary a little from required diameter, but they must be all of the same diameter.

Web plates of girders of all classes should be flat, but it is customary to allow the web of large girders to be slightly buckled or dished to the amount of say ⅜″ versed sine to a 6′ chord.

Mills do not always deliver plates perfectly straight. Have them straightened if necessary, but otherwise, when possible, use them as they are, for there is no way of straightening them except by the sledge or drop hammer, neither of which are very good for the iron. For other similar matters I can only refer to common sense and that intuitive knowledge which is the result of experience.

As to inspection at mill. An inspector can only seldom see the actual rolling of his material unless the mill men would roll only to suit his convenience, and even then it would likely be impracticable.

Tension and bending tests of the material can be made at the mill,

though where it is practicable, it is very much better to cut off and test the test pieces at the shop where the material is delivered; this can easily be done by ordering extra pieces or a few pieces of extra length. The inspection of the rolled iron, however, is best done at the shop, for there one can usually see it to better advantage, to say nothing of the fact that the most serious flaws are generally made apparent during manufacture.

My experience has been that the inspection of material at mill, except testing, generally amounts to nothing, for often times they have to load material (at which time the examination is expected to be made) when the inspector cannot be there, or after dark when he cannot see; this is not from any desire to be contrary, for though they are generally hard worked I have found shipping clerks very accommodating, but at an iron mill it requires them to use their wits to keep the yard clear.

Inspectors necessarily lose a great deal of time waiting on others. This is of daily occurrence and cannot be avoided, and such time, as a rule, must be a dead loss.

I have been asked what are the faults of some of the bridge shops. To answer that I fear might be considered as getting personal, though undoubtedly to my thinking all of them have their faults, as, with a few exceptions, they all have one fault in common, perhaps I can speak of that, viz., painting. A bridge-shop painting gang usually consists of a lot of half-grown boys led by a man who has not a very great reputation for either force or thoroughness. The chief idea of the whole crowd is to see how fast they can get over work. It seems to be of no consequence to them whether the whole piece is painted or not, for they sometimes seem to think that it is unnecessary to paint corners or unseen parts, so long as the piece looks as if it was painted. Possibly this may be a result of their being usually hurried, to say nothing of bridge shop paint-work having to be done out of doors and in all sorts of weather. I have no doubt you will smile, but I can assure you that one of the most satisfactory painting gangs I ever came across was led by a boy fourteen years old; most satisfactory, because the boy was a good foreman and saw that his gang did their work faithfully.

DRAWINGS.

The inspector seldom has anything to do with the making of drawings, but he has a great deal to do with them after they are made, and

this generally under unfavorable circumstances, consequently he is much interested in their clearness and fullness of detail.

The bridge draughtsmen should bear in mind that drawings are a species of picture-writing, used to convey to those employed in shops a clear idea of the wishes and intentions of those in charge of designing. Some individuals when writing a letter will write a good, clear, readable hand without crossing their lines, or making fantastic additions to their letters; they also express themselves fully and clearly, consequently one can read their letters rapidly yet have a complete idea of their contents. Others write a cramped, illegible hand, add fantastic scrolls to their letters, omit important words and fail generally to convey their ideas clearly. With writers of this latter style all of us know what a time it requires to find out the exact import of their letter. It is the same with drawings. Some men make their drawings so clear that they can be read at sight; others again draw in such a manner that in attempting to read their drawings you fancy that they tried to make them as much like puzzles as possible. The draughtsmen should also bear in mind that there is a difference between the style of a drawing to be made for shop use and one that is made for a periodical or other similar purpose; also, that when he uses a drawing, he has clean hands, a dry, quiet, and well-lighted place to lay his drawing and weights to keep the corners down, and paper and pencil to supply missing data; but not unfrequently the contrary of this is the case with those in the shop, and particularly so with inspectors, who often times have to hold drawings in high winds and at the same time use rule and callipers, etc. In other words, he should not make sheets too large, nor crowd too much on one sheet, nor put so many lines on top of each other that it is difficult to follow any, nor omit any figures that are required to be known at a given point because they can be found on bill of material or another drawing; thus necessitating a bill of material and a couple of drawings to know, say, what a post end should be, and he should not imagine that pieces of unfaced material are always the exact length called for.

Some may say that the draughtsman's time is expensive, and the foreman would understand this or that. True, the foreman generally can do so, but the foreman does not do the work nor stand over the men doing it, consequently he has to supply the omission of this picture writing to his men, *i. e.*, do draughtsmen's work to the neglect of his own, which, according to an old-fashioned notion, is that he should

look after the quality of the material being used, what sort of work the men were doing, and matters of similar kind, all of which was thought enough for him to do. This latter may be an old-fashioned custom, but I believe it is still adhered to in locomotive and other machine building shops.

Foremen do not always check the drawings to see if they are full and complete; unfortunately this results sometimes in work being spoiled, simply because the drawing did not state what was wanted. True, the foreman could have seen what the draughtsman had omitted if he had been doing the work himself, but his men do not necessarily have the same education and ability as he has, and drawings are as much for the men's use as for any one else.

The errors of draughtsmen, who can be called such, are not, as a rule, in the large matters, but in the small ones, which they think are unimportant and can be left to the shop. This is a fruitful cause of delay and expense, generally small, though not always so, and, in my experience, is one of almost daily occurrence; in fact, I doubt whether I have had a single span under my charge for years on which there could not have been saved a few dollars and upwards, by the draughtsmen paying a little more attention to clearness and those little things which every one knows.

Great accuracy is unnecessary in some of the parts of a bridge which it will be well to remember, as the more accurate the work is required to be the more expensive it will prove, also the fewer the parts the cheaper will be the work. Short pieces of angle iron or any small pieces fastened to a member weigh little but cost greatly.

A drawing should be clear and to the scale, with little or no shading, and when possible should be complete in itself without reference to anything else. Time saved in the drawing room is not always an economy. In making a drawing, a draughtsman should use as few different sizes and lengths of material as possible, for similarity in sizes of pins, bars, rods, and in lengths generally, saves in the cost of workmanship and reduces the chances of error. A theoretical saving of material sometimes necessitates an outlay of several times the amount saved to do the extra work, also, usually, each different form necessitates a different set of rolls for its making, which may cause delay in delivery of material. The designer should have some consideration for what is obtainable, as for instance, a variation of $\frac{1}{2}$ lb. per foot in a 12″ channel only makes a difference in thickness of web of 1-

100″ closer than it is possible to roll, unless there are a large number of same weight.

Plates and bars ordered by 1-32″, or squares and rounds ordered by 1-16″, generally come either full or scant, more likely the former. 1-32″ is looked upon in bridge shops as somewhat of an imaginary quantity, and particularly so to ask it of a blacksmith. My own experience has been that by those working on tools it is considered to mean scant or full of a given 1-16″, but a smith scarcely seems to realize what it is. Tell him a piece is to be so many sixteenths thick and he will come very near it, but ask him to make it so many thirty-seconds thick and you will be lucky if you get it within an eighth. The office says the man should be educated up to this close work, to which the shop replies that the office should be educated up to their wants. I say, that if the office wants such close work, the men are to be found, but they are only to be found in government arsenals and tool making and other establishments that require very close work.

Of late days it seems to be considered important only to be very careful to give distances of rivet spacing. This is no doubt of prime necessity to the layer-off, but not so to the machinist and inspector, the former only wants to know the distances he has to work to, and the one governing point from which he has to start; besides this the inspector usually only cares to know if the number of rivets is correct, and that their spacing is approximately so. In making drawings, distances from centre lines and other governing points should be given, and all parts that are to be planed, bored, or drilled, should be so marked. A hole or slot should always be marked with the size of the pin or tenon that it is to take; and stating what sort of fit is required. Angles are best defined by their base and perpendicular, and it should be remembered that sheared parts are not perfectly straight or smooth; that a punched hole has not parallel sides nor is it always exactly where it ought to be, and that when two or more plates are riveted together their united thickness is generally greater than the sum of their several thicknesses; that right and left pieces or other complications are to be avoided when possible, as they are troublesome and liable to cause errors; and that rivet holes should neither be too large a proportion of the width of a channel flange, nor too near its edge.

As few rivets should be left to be driven in the field as possible, for they are more expensive and less reliable than those driven in the shop. As to the latter, shop hands have every convenience possible, and are

daily occupied in driving rivets, whereas the men in the field have on the other hand almost every inconvenience to contend with, and driving rivets is but a very occasional part of their work.

TESTS.

Looking over the results of a large number of specimen tests of wrought iron made by myself, I find that the results are about the same for bars, rods, plates (edge rolled), angles and channel bars, viz., an ultimate strength of from 50,000 to 53,000 lbs. per square inch, generally 51,000, and an elongation in 6″ of from 16 per cent. to 25 per cent. channel bar webs, and plates ranging chiefly from 16 to 20 per cent. This I think is due very much to the fact that in the test pieces made from these, it was necessary to use a rectangular section. I have tested sheared plates up to 72″x$\frac{3}{8}$″ with the same ultimate strength as the above, but the elongation varying from 9 per cent to 16 per cent.

Bending Tests.—Bars, rods, and channel flanges with few exceptions bent until flat or their ends touched with a curvature, whose diameter varied from one-half to three times thickness of piece, generally one and a half. Plates and channel webs would bend 150 degrees, or until their ends touched with a curve whose diameter ranged from one to four times thickness. All bending pieces were about one foot long, and from 2″ to 3″ wide. Here it may be well to say that bending pieces must not be sheared but planed, and also have their edges well rounded on a grindstone or emery wheel, so as to remove any incipient cracks.

These are tests of such wrought iron, with but few exceptions, as has been used in the work that I have had charge of during the last six years. Of course all will understand, that these tests were applied in line of fibre, as is the ordinary usage.* Where more than this is expected, viz., a strain, crosswise to fibre, it is always specially mentioned, as witness British Admiralty and other specifications The reduction of area has been omitted, as the measurements taken for it are generally unreliable, and as Stoney says, the elongation is much more reliable for any question as to quality of iron.

I have other tests, which are of condemned lots, but presume they would be of no interest, for surely no one is going to try for the worst material he can get. I have had but little to do with cast iron, since

* See table for transverse strength of plates.

testing has become common, but have about 12 or 15 tests from as many heats. In these, the bars 1″ sq., 5′ long, 4′ 6″ between supports, it took from 650 to 700 lbs. resting on dull knife edge at centre to break them, which was a better result than asked for. Of course the foundry hands took good care to place the bar on supports, same side up, as when cast. Such cast iron should only be used in very special cases, for it is certainly much too good to be used in such places as masonry plates, and washers of bridges.

Thus far I eave only tested steel from plates rolled in this country from English Bessemer blooms. I made a large number of tests from these plates, both tension and bending; of the latter there were over 100. The plates ranged in size from 12″x $\frac{1}{4}$″ to 24″ x $\frac{3}{4}$″. The results were very uniform, giving an ultimate strength averaging 70,000 lbs. per square inch, with an average elongation of 30 per cent in 6″. The bending pieces were planed from plate shearings very little broader than the test piece. All these were well rounded on grindstone, heated red hot, and dropped into water of a temperature from 70 to 100 degrees. Nearly all bent 180 degrees flat, some few of those $\frac{1}{2}$″ to $\frac{3}{4}$″ cracked at edges when 90 degrees; these latter were then punched within $\frac{1}{4}$″ of edges without cracking, probably there were invisible edge cracks.

Some of you, no doubt, would like to know what strain full size pieces, just as they go into a bridge, will stand. I have enough of one kind, I think, to satisfy you, viz., of tension members. I have made a few tests of compression pieces which have been published elsewhere.

I will first give you the result of four lots of bars, ranging from 1″ to 2″ diameter, and from 15′ to 25′ long with enlarged ends for thread.

1st lot consisted of 60 iron rods. 14 of these broke in thread, the rest in the body of the bars with 12 to 19 per cent. elongation. All except four stood over 45,000 lbs. per square inch; one of these broke at 35,000 lbs., two at 40,000 lbs., and one at 43,000 lbs. per square inch.

2d lot; 23 rods. 13 broke in screw, the others elongating 12 to 16 per cent. All but one stood over 45,000 lbs.; that one stood 44,000.

The above are only moderately good.

3d lot; 38 rods. 11 broke in screw, the others elongating 13 to 18

per cent. All but seven stood 50,000 lbs. or over; these broke as follows:

1—38,000	lbs.	per	square	inch.
1—42,000	"	"	"	"
1—43,000	"	"	"	"
1—48,000	"	"	"	"
3—49,000	"	"	"	"

4th lot; 30 bars. Two broke in screw. All stood 50,000 lbs. per square inch or over. Elongation of those that broke in bar, was from 10 to 18 per cent. generally 16 per cent; nearly all these broke within 2 feet of end of rod, as did those in the other lots.

Another lot of 20—1$\frac{3}{8}''$ round rods with 1$\frac{3}{8}''$ threads (all of course in thread) broke with 37,000 to 40,000 lbs. per square inch of rod.

Before proceeding further, I may as well state here, that the above lots of rods were made by different shops, as were also the eyebars, the test results of which I am about to give you. These I have classed by width of bar, as it will give you as good an idea of the average eyebar as any other classification.

I will first give you the results of tests of some heads made entirely by upsetting, merely saying that they have been given to me, and that I did not see the tests made:

Of 52 bars about 3$\frac{1}{2}''$ wide, 22 broke in bar, elongating 7 to 15 per cent., and 30 broke in the head. The ultimate breaking strains seemed too high, consequently I omit them, excepting to say that one broke in the head at 36,000 lbs. per square inch, and two others at 42,500 lbs.

Next I will give you results of tests of eyebars made by piling. With the exception of some 10 or 12 bars, the iron in all of them showed a good fibrous fracture, and with very few exceptions, perhaps six, the heads were proportioned by usual formula.

Of 26 6$''$ bars, 13 broke in bar with following strains:

5	between	40,000 and 45,000	lbs.	per	square	inch.
6	"	45,000 and 47,000	"	"	"	"
1	"	47,000 and 49,000	"	"	"	"
1	"	49,000 and upwards	"	"	"	"

13 broke in head.

11	between	42,000 and 45,000	lbs.	per	square	inch.
2	"	45,000 and 48,000	"	"	"	"

Of 159 5″ bars, 80 broke in bar:

2	between	35,000 and 40,000	lbs.	per	square	inch.
10	"	40,000 and 45,000	"	"	"	"
17	"	45,000 and 47,000	"	"	"	"
27	"	47,000 and 49,000	"	"	"	"
24	"	49,000 and upwards	"	"	"	"

79 broke in head—one at 33,000 lbs.

6	between	35,000 and 40,000	lbs.	per	square	inch.
36	"	40,000 and 45,000	"	"	"	"
22	"	45,000 and 47,000	"	"	"	"
11	"	47,000 and 49,000	"	"	"	"
3	"	49,000 and upwards	"	"	"	"

Of 46 4″ bars, 26 broke in bar:

3	between	40,000 and 45,000	lbs.	per	square	inch.
11	"	47,000 and 49,000	"	"	"	"
12	"	49,000 and upwards	"	"	"	"

18 broke in head—one at 37,000 lbs.

10	between	40,000 and 45,000	lbs.	per	square	inch.
1	"	45,000 and 47,000	"	"	"	"
4	"	47,000 and 49,000	"	"	"	"
2	"	49,000 and upwards	"	"	"	"

Of 19 3″ bars, 14 broke in bar:

5	between	45,000 and 47,000	lbs.	per	square	inch.
3	"	47,000 and 49,000	"	"	"	"
6	"	49,000 and upwards	"	"	"	"

5 broke in head:

1	between	40,000 and 45,000	lbs.	per	square	inch.
2	"	47,000 and 49,000	"	"	"	"
2	"	49,000 and upwards	"	"	"	"

From the foregoing it seems to me that these results should be called good when

6″	bars	break	at	45,000	lbs.	and	upwards.
5″	"	"	"	46,000	"	"	"
4″	"	"	"	47,000	"	"	"
3″	"	"	"	48,000	"	"	"

With an elongation of not less than 10 per cent. nor more than 25, to be measured in not less than 5′. Bars of same rolling even when broken in the body will give differences in elongation ; 14 to 16 per

cent, however, is the most common elongation in the above tests. They will also break at different strains; *e. g.* 6″x ¾″ bar broke at 46,800 lbs. per square inch, elongating 12 per cent., when a 6″x 1⅛″ bar broke at 49,500 lbs., elongating 15 per cent. One 3x1⅛″ bar broke at 46,000 lbs. per square inch, elongating 17 per cent., another 3x1⅛″ bar broke at 50,000 lbs., elongating 17 per cent., all of which bars, I believe, were rolled from exactly the same stock, and seemed to me to be purely fibrous and without flaw. All who have done much testing, know that results will sometimes vary in test pieces cut from the same piece of iron, to wit, a ¾″ round; but the above variations, seem to be greater than is due to this cause. Some say it is the result of unknown factors in the manufacture; perhaps the effect of heating only a portion of the bar. Is it so?

Some tests made at Watertown on 5″ and 3″ flats 10′ long showed even better than this, but all those bars were rolled specially for the test, had no rough handling, and were not heated or worked on after leaving the rolls. From these and other tests it seems probable that all double-rolled iron bars will, if tested as they leave the rolls, stand from 50,000 to 52,000 lbs. per square inch ultimate strength, with an elongation of 15 to 23 per cent.

Some lay stress upon having a bar break in the shank. I do not think it so essential, though I prefer it, for when the bars have elongated 8 per cent., the bottom chords and ties will have lengthened so much that the bridge will, most likely, fall between its abutments.

I append a table of some tests of eyebars, but wish to give results of three here:

5″x1⅜″ bars had an elastic limit of 27,000 with an ultimate strength of 37,800, broke 6′ from pin, little or no weld. Moral rolling mills do not always pile full length piles. I am very sorry to say, I could show others like this, and testing to destruction is often the only way of discovering this defect.

A 5″ x 1⅛″ bar, 12′ centers had an elastic limit of 33,000 lbs., but broke with 33,500 lbs.

A 5″ x 1 7-16″ bar, 15′ 3″ center, pins 4⅜″, had accidentally been strained beyond its elastic limit, being lengthened thereby ¼″; pinholes had a slight set, say 1-100″. Elastic limit supposed to have taken place at 31,000 lbs. This bar was loaned to me, provided I did not stretch it any more. I put the bar into press with 4⅛″ pins, and applied a strain of 15,000 lbs. per square inch, holding it 5 minutes;

released this, and applied a strain of 20,000 lbs., which was likewise held 5 minutes and released. Finally a strain of 24,500 lbs. was applied for 5 minutes. The pin-holes were then measured; both measured the same, viz., 4 25-64″ transverse to bar, and 4 13-32 in line of bar.

The test of 5″ x $1\frac{3}{8}$″ bar is given to show that rolling mills are not always careful, even when paid for extra good iron. That of 5″ x 1 7-16″ bar is given to show that with properly proportioned heads it is not necessary to make pins fit holes so very accurately as is oftentimes required. I do not, however, advocate such a difference as this between pins and pin-holes, but I do not think that it is allowable to make pin-holes 1 32″ larger than pins for diameters of 4, $4\frac{1}{2}$″, and upwards.

Neither 5″ x $1\frac{3}{8}$ nor 5″ x $1\frac{1}{8}$″ bars gave any intimation of their yielding until their elastic limit had been very nearly reached.

By some, great stress is laid upon applying a proof-strain. I have personally tested several thousand bars and rods of all styles of make, but never found one defect by this proof-strain. Indeed, I have subjected eyebars with visible defects to this strain; and although I have closely watched them, nothing more could be seen than before the bar was under stress.

I have found proof-strains serviceable only with small things that were considered of no importance by the smith.

Whenever the matter is left to me I never use a proof-strain, except where the ends are welded to main body of bar or rod, *i. e.*, finished bar longer than original bar, and then not that I expect it to be of any service, but because I considered it to be a safe plan to examine a weld in every possible way. In place of proof-strains, I should advise, in addition to this, that a number of extra tension pieces should be ordered; and when the whole lot are finished, that as many be chosen as were ordered extra, and then break them; but not till all are finished. The cost will not be great, and I am sure it will have a good effect, for having tried it on a small scale, I have found it to work wonderfully well. So I may say I speak to some extent from experience.

Some railway companies require the modulus of each bar to be taken. In my experience this cannot be done with any accuracy with such appliances as are to be found in shops. To be accurate, the bar ought to be counterbalanced at say every ten feet with movable

weights, so as to eliminate the effects of any sagging which is produced by weight. The pressure-gauges should read accurately and not approximately, and much more time given to it than ordinary shop testing will admit of.

I have tested over 5,000 bars for their moduli, and all the results I have obtained lie between a modulus of 24,000,000 and 30,000,000, or say extensions of .008″ to .01″ per foot for 20,000 lbs. strain.

Generally at any one testing the moduli did not vary more than 3,000,000, of which the equivalent variation in extension would be .001″ per foot.*

In my opinion, even this is greater than it would be if all sources of error were eliminated, for I am inclined to believe, on looking over the tests I have made, that the modulus of the iron (from three different mills) I have tested lies between 26,000,000 to 28,000,000, or the equivalent extensions of from .0092″ to .0086″ per foot to 20,000 lbs., and that the extremes are perhaps even less than here given.

Since writing the foregoing, I find that in Watertown tests of 2510′ bars of two different classes of iron from two different mills, making the lot referred to above, the extension of 21 for 20,000 lbs. strain was within the above limit; the others had the following: .0093″, .0084″, and .008″ per foot. I feel inclined to think that this last ought to be omitted. Taking them as they are for 10,000 lbs. strain per square inch, the variations in bars 30′ long would be .021″, or one and a half sixty-fourths of an inch. In six bars rolled at one mill, the difference of extension for 20,000 lbs. strain was .00048″ per foot, which would be for a 30′ bar with 10,000 lbs. strain, 1-128″ nearly.

As so much testing of bars has been done, perhaps it would be well to state the different ways of making iron eyebars. As to design, the heads may be square, octagonal, circular, pear-shaped, or an oval, made by striking the curves forming eye, from two centres with same radius, and connecting them by tangents. This is done to give a greater proportion of metal back of eye, which, I think, is very judicious, because it makes some allowance for the inaccuracy of the smith, and experience convinces me that it aids very greatly in preventing

* These elongations for moduli were taken between strains of 10,000 lbs. and 20,000 lbs. per sq.″; previous to adopting this method the elongations were taken between strains of zero to 20,000 lbs. per sq.″, and I then obtained as great variations as you can find published, for the unsupported length of bar was the greatest factor in the result.

NAME OF VESSEL.	Diameter of cylinder in inches.	Pressure per square inch on piston, in pounds.	Total pressure on piston, in pounds.	No. of strokes of piston per minute.	Length of crank-pin in inches.	Diameter of crank-pin in inches.	Square inches of projected area of crank-pin.	Velocity of rubbing surface of crank-pin, in feet, per minute.	Total work of friction of crank-pin in foot-pounds per minute, the co-efficient of friction being 0·05.	Work of friction on a square inch of projected area of crank-pin, in foot-pounds per minute.	Pressure per square inch of projected area of crank-pin, in pounds.	Work of friction on crank-pin, transmuted into heat units per hour.	Heat units per hour, per square inch of projected area of crank-pin.	REMARKS.
U. S. S. Despatch	33⅛	21·8	18787·24	129	8	9	72	151·97	142,748	1982·6	260·93	11094·4	154·0	JOURNAL OF THE FRANKLIN INSTITUTE, 1882.
" "	33¾	21·8	19084·34	129	8	9	72	151·97	145,010	2014·0	265·06	11270·2	156·5	
" Essex	34	28·0	25421·20	152	16	10	160	198·968	252,900	1580·6	155·88	19643·5	122·7	Edwards' "American Marine Engines."
" "	51	12·0	24513·60	152	16	10	160	198·968	243,870	1524·2	153·21	18553·6	118·4	
" Galena	42	28·8	39890·10	130	18½	10½	194·25	178·678	356,370	1094·2	205·35	27697·1	142·0	1,100 designed HP. equally divided between the two cylinders.
" "	64	12·3	39890·10	130	18½	10½	194·25	178·678	356,370	1994·2	205·35	27697·1	142·0	
" Miantonomah	32	36·0	28952·40	130	15	9⅝	144·375	163·78	233,810	1619·5	200·54	18171·7	125·9	Designed HP. of engines equally divided between the cylinders.
" "	48	16·0	28952·40	130	15	9⅝	144·375	163·78	233,810	1616·5	200·54	18171·7	125·9	
" Quinnebaug	42	32·9	45570·60	122	17½	10½	183·75	167·68	384,425	2092·1	248·05	29877·6	162·6	Trial trip up Chesapeake Bay, December 6, 1878.
" "	64	12·4	39890·80	122	17½	10½	183·75	167·68	336,360	1830·5	217·09	26129·0	141·1	
H. M. S. Alexandra	70	23·0	88515·60	134	17½	17½	306·25	306·96	1,358,590	4430·2	289·03	105590·0	312·1	King's "War Ships of the World."
" "	90	14·0	89063·80	134	17½	17½	306·25	306·96	1,366,900	4463·3	290·82	106235·7	314·2	King's "War Ships of the World."
" "	90	14·0	89063·80	134	17½	17½	306·25	306·90	1,366,900	4463·3	290·82	106235·7	314·2	King's "War Ships of the World."
" Garnet	57	26·0	66340·80	160	13	13	169	306·27	1,016,120	6012·5	302·58	78773·0	455·5	King's "War Ships of the World."
" "	90	10·2	16797·85	160	13	13	169	306·27	1,023,000	6053·2	305·25	79507·7	470·4	King's "War Ships of the World."
" Rover	72	37·0	150645·50	138	14	20	288	356·048	2,681,950	9578·4	538·02	207146·4	739·8	"Engineering," 1876.
" "	88	12·0	72985·20	130	14	20	288	356·048	1,299,300	4640·3	260·66	100968·9	360·6	" "
" "	88	10·5	63862·050	136	14	20	288	356·048	1,136,900	4060·3	221·50	88347·1	315·5	" "
" Téméraire	70	29·0	111606·50	147·2	17½	17½	306·25	330·198	1,876,170	6120·2	364·43	145816·3	470·1	King's "War Ships of the World."
" "	114	11·0	112277·66	147·2	17½	17½	306·25	336·198	1,887,500	6163·2	366·62	146690·9	478·9	King's "War Ships of the World."
U. S. F. C. S. Fish Hawk	22	30·40	11589·25	206	6½	4¾	30·875	128·085	74,215	2403·7	375·38	5768·0	186·8	H. P. cylinder of engine.
S. S. City of San Francisco	51	27·3	55768·44	92	18	16	288	192·685	537,290	1665·6	193·64	41758·3	145·0	Edwards' "American Marine Engines."
" "	88	6·36	50815·356	92	18	16	288	102·685	489,870	1700·9	176·61	38072·8	132·2	Edwards' "American Marine Engines."
" City of Tokio	51	27·3	45768·44	102	17	16	272	213·628	695,675	2557·8	205·03	54068·0	198·1	Edwards' "American Marine Engines."
" "	88	10·8	65670·68	102	17	16	272	213·628	701,465	2578·9	241·43	54518·0	200·4	Edwards' "American Marine Engines."
" Leerdam	39½	36·8	44094·72	124	12½	12	150	194·779	429,420	2862·6	293·96	33374·7	222·5	"Engineer," 1882."
" "	69	10·54	39412·22	124	12½	12	150	194·779	383,830	2558·0	262·81	29831·3	198·9	" "
Yacht Leila.	16	20·409	4102·209	443	3½	3⅞	13·5625	224·705	40,090	3396·9	302·52	3582·1	264·1	Report to Bureau of Steam Engineering, U. S. Navy Department.
" "	9	53·756	3410·419	443	4½	2¼	10·125	130·475	22,308	2203·2	337·72	1738·8	171·2	
S. S. Ohio	57¼	33·0	84948·60	120	20	16	320	251·328	1,067,480	3335·9	265·46	82964·7	259·2	"Engineering," 1876, and King's "War Ships of the World."
" "	90⅛	7·6	48483·44	120	20	16	320	251·328	609,255	1903·9	151·51	47351·4	148·0	
Averages of 31 pins	....	....	....	....	....	....	....	....	....	3309·9	269·15	....	259·1	
Best 10 results	....	....	....	....	....	....	....	....	....	5086·6	365·41	....	387·1	

any deformation to the eye; for when so made, and other proportions as usual, it is extremely rare for them to break at pin-hole. Old English tests, and also those of Chief Engineer Sprague, of the navy, confirm this. Generally the third and last shaped heads are used; they may be either same or greater thickness than the bar, and are connected to the bar by the neck, which is formed of curves of greater or less radii.

As to manufacture:

1st. These heads may be cut out of a rolled plate, or may be forged from billets, and welded to the bar.

2d. The body of the bar may be upset to form the head, without the addition of any extra metal.

3d. Piling pieces are put on end of bar, and the whole partially upset, after which they are pressed or hammered into shape in a die.

4th. Same as last, omitting upsetting.

5th. Is the Springer patent. This is made by bending a piece of iron of proper size and same thickness as a bar, requiring head into somewhat the shape exteriorly of a horse-shoe, with a rectangular slot on the inside. This is slipped on to end of bar, and cover-plates, cut to shape, placed on top and bottom. The whole is then heated, and pressed or hammered into a die, as above.

6th. Is the Kloman bar, with which you are all acquainted.

7th. Is the loop eye, which is formed by bending the bar edgewise around a pin and welding edges together.

No. 1, or welded bars, are nowadays considered inadmissible.

No. 2, or upset bar, makes a very good bar, and the manufacture of it will probably be improved, but I am inclined to think it would be better if they used a little piling.

Nos. 3 and 4, or piled head, is the one in most general use, and makes a very good head; but care should be taken to keep the diameter of the eye and radius of neck as small as possible, the difficulty of manufacture increasing with diameter of eye, and the bar should not be too thin to hold its heat, nor should the head be piled crosswise

5th. The Springer bar gives any desired latitude to size of head. All bars of this make that I have seen tested broke entirely clear of the head, except one, which broke at pin-hole at 49,600 lbs., the head having an excess of only 31 per cent. I have broken four heads longitudinally and transversely, all of which showed solid welding.

6th, or Kloman. This makes a very good bar; but the only tests I

have of these were made on bars Mr. Kloman tested for his private use.

The 7th, if made by a good smith, will, I believe, always break in body of bar.

For steel bars, heads are designed after same pattern as those of iron, but with them welding or piling is not permissible, so that either a Kloman head or one made by upsetting is here necessary. The Edge Moor Iron Co. has a plant for upsetting steel bars. At the time I examined it I was fully convinced that the process could not fail to make a good head; I have since been told that all that had been tested broke near centre of bar when properly annealed—*i. e.*, whole length at one time; if only annealed at ends, they broke near where effects of annealing ceased.

The annealing of steel eyebars appears from tests to be a matter of considerable importance.

As to round and square rods, they have eyes and enlarged ends for screws, made after the same modes as eyebars, except that the diameter of the ends of iron bars are sometimes increased by piling or splitting the bar, putting in a wedge, and welding all up.

I intended to have embraced specifications as a part of my subject, but I have detained you long enough. I hope some one will give us a paper on this subject, and in it show that some specifications ask for impossibilities; that others have costly manufacturing requirements, which are omitted after the work is let, and that much also could be done to relieve the labor of estimating by adopting a standard column formula and by adopting rolling loads at so much per foot, or, at least, using standard engines.

Results of Tests of Eye Bars with Heads made with Piling Pieces—Tests made with Hydraulic Machines fitted with Mercury Gauges. Bars varied in Length from 10′–0″ to 25′–0″.

Size of Bar in inches.	Elastic Limit in Pounds per square inch.	Breaking Strain in Pounds per sq. inch.	Per cent. of Elongation.	Distance of Fracture from nearest Pin Centre in inches.	REMARKS.
6x1⅝	24,500	43,700	11	....	Broke at head.
6x ¾	30,000	47,000	13	....	" " "
6x1	27,000	40,500	5	12	Granular.
6x1	27,000	42,200	7	24	"
6x1 9/16	25,600	45,800	21	32	Fibrous.
6x1	29,900	46,500	13	17	"
6x ¾	30,600	46,800	12	15	"
6x1 3/16	28,800	47,400	15	32	"
6x1⅛	28,000	49,500	15	21	"
5x1⅛	28,300	43,500	10	....	Broke at head.
5x1	31,000	46,000	8·5	....	" " "
5x1	28,000	47,000	9	....	" " "
5x1 5/16	29,000	48,700	11·5	....	" " "
5x1 7/16	25,800	37,000	4	24	Granular.
5x1⅜	26,500	37,800	5	66	Fibrous. Bar not welded.
5x1	31,000	42,000	4	....	In bar, distance and character of fracture not noted.
5x1	28,600	45,000	14	85	Fibrous.
5x1⅜	28,000	46,500	9·5	21	"
5x1	29,000	49,000	16	21	"
5x1¼	30,000	49,000	14	20	"
5x1	30,000	50,000	16	20	"

Results of Tests of Eye Bars, Etc., Continued.

Size of Bar in inches.	Elastic Limit in Pounds per square inch.	Breaking Strain in Pounds per sq. inch.	Per cent. of Elongation.	Distance of Fracture from nearest Pin Centre in inches.	REMARKS.
5x1½	30,000	50,000	16	20	Fibrous.
5x1$\frac{3}{16}$	30,400	51,000	15·2	60	"
5x1	31,000	51,000	15	136	"
4x1¼	28,000	43,000	10	....	Broke at head.
4x1$\frac{1}{16}$	30,000	48,600	12	....	" " "
4x1⅛	29,000	45,000	13	80	Fibrous.
4x1$\frac{5}{16}$	27,300	47,500	18	21	"
4x1¼	29,000	47,800	15·5	26	"
4x ⅞	34,000	48,000	6·8	24	Granular.
4x1¼	27,400	48,000	13·3	16	Fibrous.
4x1⅛	28,300	48,500	16·6	18	"
4x1$\frac{3}{16}$	28,700	48,700	14	20	"
4x1	30,500	49,200	13	12	"
4x1¼	30,000	49,600	16	13	"
4x ⅞	32,000	49,800	15	24	"
4x ⅞	29,700	50,000	16	20	"
4x1	31,800	50,000	15	....	" Broke in bar, position of fracture not noted.
3x1⅛	30,000	46,000	17	24	Fibrous.
3x ⅞	30,600	46,400	14	24	" Broke in bar position of fracture not noted.
3x1	....	50,000	12	....	Fibrous.
3x1⅛	31,700	50,000	17	22	"
3x1¼	32,000	50,000	15·3	22	"

Results of Tests of Iron Plates—Tension Tests made with Lever Machines.

	Lengthways.					Crossways.			
	Thickness in inches.	Ultimate strength per square inch in pounds.	Per cent. elongation.	Elongation measured in inches length.	BENDING.	Ultimate strength per square inch in pounds.	Per cent. elongation.	Elongation measured in inches length.	BENDING.
A	¼	52,000	20	6	180° flat.	29,500	2.2	4	20° to 3″ circle.
"	⅜	50,500	19	6	180° flat.	31,400	1.5	4	25° to 9″ "
"	⅜	51,000	21	6		31,300			
"	½	51,000	21	6	180° to 1¾″ circle.	31,500	3	4	25° to 9″ "
"	½	52,000	23	6		33,400	2.5	4	15° to 4″ "
"	⅝	51,000	17	5	Ends touching to ⅝″ circle.	28,900	2	5	25° to 9″ "
B	⅜	50,700	9.4	8	Ends touching to 1″ circle.	36,500	2	3	30° to 3″ "
"	⅜	51,000	9.5	8	Ends touching to 1½″ circle.	36,000	....	....	60° to 5″ "
"	⅜	50,600	13	6					
"	⅜	51,600	13	6					
"	⅜	51,700	17	6					
"	7/16	51,000	....	....	160° to 2″ circle.	39,000	2.3	3	
"	7/16	50,500	9.2	8	170° to 2″ "	31,400	2	3	40° to 6″ "
"	7/16	51,500	12.7	8	170° to 1″ "	38,000	3	3	
B	⅜	46,400	13	8	180° to 1″ "	31,800	0.6	8	
"	½	50,800	11.7	8	180° to 2″ "	32,600	1	8	
C	¼	53,700	7	10		not	given.		
"	½	49,300	6.7	10					
D	½	47,500	9	10		42,500	2.7	10	
"	¾	47,900	10	10		41,900	3.8	10	
E	⅜ to ⅝	47,700	16.7	10		45,500	11.2	10	

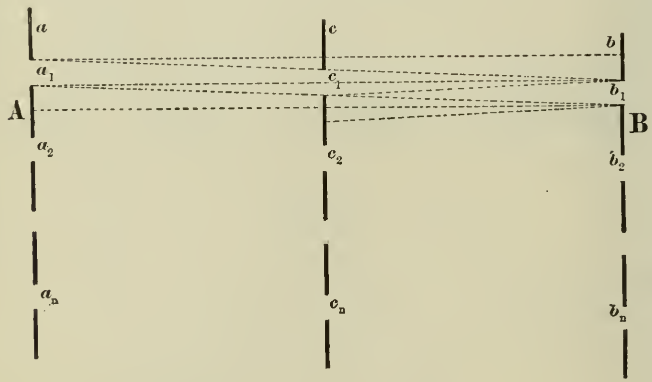
Tests A were from American edge-rolled bridge plate.
" B " " sheared "
" C " " ordinary English ship plates.

Tests D were from ordinary English boiler plates.
" E " " Yorkshire wrought iron plates.
" C, D, and E are a mean of several tests made by Mr. Kirkaldy.

RADIANT HEAT AN EXCEPTION TO THE SECOND LAW OF THERMO-DYNAMICS.*

By H. T. Eddy, Ph. D.

Since the radiation of heat takes place by propagation through space at a certain finite velocity, and not instantaneously, it is quite possible for occurrences to intervene during the exchange of radiations between two bodies, such as to essentially change the distribution of heat which would otherwise have ultimately taken place.



To make this evident, let us first employ a mechanical analogy. In the accompanying figure, let there be three parallel screens a, b, and c, the latter between the two former, and all three perpendicular to the plane of the paper. Let them be pierced respectively by a series of equidistant apertures a_1 a_2 a_n, b_1 b_2 b_n, c_1 c_2 c_n, situated in the plane of the paper, and let these apertures be so placed that a_1, b_1, c_1, are upon one straight line, not quite at right angles to the screens; then are a_2, b_2, c_2, etc., and a_n, b_n, c_n, upon lines parallel to a_1, b_1, c_1. Now conceive the screens a, b, c, to have a common uniform velocity, u, in the direction from c_2 to c_1. Also, let a series of projectiles be discharged from any fixed position, A, at the left of the screen a, at such instants as to pass the first one through the aperture a_1, the second through a_2, etc.,

* From the Proceedings of the Ohio Mechanics' Institute, May 25, 1882.

and let the direction of discharge be perpendicular to the screens, and the velocity, v, such that each one shall just reach the screen b in time to pass through the first aperture of that screen which crosses its path. Then would the screens a b c in no way interfere with the passage of these projectiles. Let us denote the space at the left of a as the space A, and that at the right of b as the space B. Then, if there be a continuous discharge of projectiles from all points of the space A, only a part of them can pass through the apertures of a. Such, however, as succeed in passing a, will pass b and c also. Again, let a second discharge of projectiles take place from the space B, but directed toward the left perpendicularly to the screens, so that these projectiles move in a precisely opposite direction from those first mentioned. Let the projectiles from B have the common velocity v'. Such of these projectiles as succeed in passing through the apertures of b will impinge on c at points between its apertures, in case c be placed at a proper distance from b. Let the surface of c which faces b be perfectly reflecting, and let the parts between its apertures be either concave, or a series of inclined planes, so directed that each of the projectiles on rebounding will pass back through one of the apertures in b. When the velocity v' of the projectiles is large compared with that of the screens u, the projectiles can be made to return through b very nearly perpendicularly, either by returning each projectile through that aperture from which it started or through some following one.

The paths of the projectiles relative to the screens can be readily found by impressing upon the projectiles, in addition to their velocities v or v', a velocity—u, numerically equal and opposed to that of the screens, while the screens themselves are at rest. The composition of these velocities will give the required relative velocity.

In order to apply the mechanical analogy just considered to the case in hand, let us replace the supposed projectiles by radiations which emanate from warm bodies situated in the spaces A and B, and let the only radiations at first considered be those in a direction perpendicular to the screen.

It is then evident that with such a series of apertures as are represented in the figure, the screens a b c could be given such a velocity u, as, accompanied by reflections from c, would transfer radiations from the body A to B, unaccompanied by a compensating transfer from B to A; and thus the body B would be heated at the expense of A.

Even if radiations at the apertures in a and b be not confined to rays perpendicular to the screens, but take place instead in the manner usual at plane surfaces, it is still evident that the usual interchange of radiations has been effectively interfered with, and that the body B would be heated at the expense of A. In case the radiations from the body B are reflected back through the same apertures from which they started, it is quite unnecessary to have the series of apertures in the screen a at equal distances; it is only necessary that the series of apertures in b and c correspond to those in a. Indeed, each aperture in b can be conceived to be completely surrounded by a concave semi-cylindrical reflector attached to c, of such a form as to return to b all radiations from it when moving with the velocity u. This can certainly by effected if the apertures in b are mere points, and can be closely approximated to when they are small. Now, if there be in this cylinder a proper aperture for the admission of the normal radiations from A through a, it is evident that the radiations passing through this aperture from B, being oblique, are, when the bodies are of equal temperature, less than those of A passing through the same aperture, according to the well known law of radiations that the intensity is proportional to the cosine of the angle between the ray and the normal to the radiating surface. It is seen that with a sufficiently large value of u, it would be possible to overcome any difference of temperature, however great.

In order to form an estimate of the amount by which the radiation from A to B exceeds that escaping from B through c, let us suppose that the temperatures of A and B are equal, and that the velocity v of the radiations from A and B is the same; and, further, let the screen c be midway between a and b at a distance p from each. Let the problem be to compute the ratio between the radiations which pass through a given aperture, as c_1, from a_1, and from b_1, respectively, on the supposition that the heat radiates from the equal apertures a_1 and b_1, as from plane surfaces, in the usual manner.

Suppose that the linear dimensions of the apertures are infinitesimal compared with p, and let the letters a_1 b_1 c_1, considered as numerical magnitudes, designate the areas of the apertures a_1 b_1 c_1 respectively. Let θ be the angle between a ray and the normal to the surface from which it radiates. Let a sphere of radius p be supposed to be described about some point of b_1 as a centre, and let s be the area of that part

of its surface included within the cone of rays passing from the centre to the periphery of the aperture c_1;

$$\text{then } \frac{s}{p^2} = \frac{c_1}{r^2} \cos\theta \tag{1}$$

in which r is the distance passed over by the ray from b to c.

$$\text{Also } p = r \cos\theta \tag{2}$$

$$\text{therefore } s = c_1 \cos^3\theta \tag{3}$$

Now the heat radiated from b_1 is directly proportional to the area b_1, to the area s, and to $\cos\theta$, but inversely proportional to p^2;

$$\text{hence } \frac{b_1\, s}{p^2} \cos\theta = \frac{b_1\, c_1}{p^2} \cos^4\theta \tag{4}$$

is proportional to the heat radiated from b_1 through c_1.

Similarly,
$$\frac{a_1\, c_1}{p^2} \tag{5}$$

is proportional to the heat radiated from a_1 through c_1, since it passes c normally. Now the heat passing from b_1 to c_1 must evidently move in a direction to overtake the aperture c_1, and to do this it must evidently take a direction such that θ is defined by the equation

$$\tan\theta = \frac{2u}{v}, \text{ or } \cos^2\theta = \frac{v^2}{v^2 + 4u^2} \tag{6}$$

Hence, by comparing expressions (4) and (5), and substituting from (6), it appears that the heat radiated from a_1 through c_1 is greater than that radiated by an equal surface b_1 through c_1, in the ratio of $(v^2 + 4u^2)^2$ to v^4, in case the temperatures of a_1 and b_1 are equal. If the temperature of a_1 were lower than that of b_1, this ratio would be diminished; but by increasing u, the ratio can still be made to exceed unity, thus confirming the observations previously made. Neither is it essential that the radiations all take place at the same velocity. The reflectors can be arranged for some one velocity, and they will then send back the radiations to B, which have that velocity.

Perhaps the most simple ideal arrangement for effecting the proposed interference with the radiations naturally taking place between two bodies, is to suppose the apertures distributed around the circumferences of equal circles, upon three parallel disks fixed upon a common central axis, so that the plane of the paper in the figure becomes the surface of a circular cylinder, in which case the required velocity u can be given to the apertures by simple rotation. Let us for brevity call such an

arrangement a *radiation syren*, or simply a *syren*, as it slightly resembles in its mechanical details the acoustic instrument called by that name. Now, theoretically, no expenditure of energy is necessary to preserve the uniform velocity of the moving parts of this syren; and once started with a sufficiently high velocity of rotation and proper adjustment of reflectors, it would transfer heat from the body A to B, regardless of their temperatures, provided no radiations are permitted except those perpendicular to the disks, excluding, of course, all radiations to and from all bodies other than A and B. It would also, as before shown, transfer heat from a colder body to a hotter, even though the radiation follow the general law of radiations from plane surfaces.

It is needless to state that the action of the syren, regarded as a possible physical process, is directly at variance with hitherto accepted axioms and conclusions respecting the second law of thermo-dynamics. It is true, we should at first thought be inclined to the belief that the laws of heat should suffer some modification, in case we assume differing rates of propagation not infinite, but we should hardly be prepared to admit the startling conclusions which must flow from such modification, if the physical process just sketched be admitted to be valid; and these I shall now proceed to develop.

I think it may be readily perceived that the axioms of Clausius, upon which he founds the second law, viz., that "heat can not of itself pass from a colder into a hotter body," when applied to radiations, implicitly assumes that the heat is radiated with infinite velocity; for it takes no account of the states of relative rest or motion of the bodies between which heat passes.

The axiom of Thomson, "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of surrounding objects," is obnoxious to the same criticism; and, as I have stated elsewhere,* these should not be called *axioms* at all, since we are not in a position to bring sufficient experience to bear upon them to affirm their validity or want of validity. Indeed, if the process of the syren be admitted to be possible, we are now in a position to assert that there exists an unexplained contradiction, which does not permit us to consider them as applicable to radiations of heat propagated at finite velocities.

*Thero-dynamics, New York, 1879.

What, it seems to me, the statements of Clausius and Thomson just quoted, really asserted, was the historical fact that at the date when they were made no one had as yet invented any machine, or discovered any principle on which it was possible to construct a machine, which could successfully accomplish what these said had not been done; and it was further implied that no such machine could probably ever be invented, nor any such principle discovered.

In complete accord with this statement is that of Kirchhoff, made in his lectures upon the Theory of Heat during the summer semester of 1880, in which he said, if correctly reported, that the second law can not be (at present) proved; but it, so far, has never been found in disagreement with experience.

It is well known that Maxwell has proposed a process to accomplish this very object; namely, to transfer heat from a colder to a hotter body, in the following manner: If we suppose minute beings, endowed with senses sufficiently acute, and having a corresponding agility to guard minute openings in the diaphragm separating two portions of the same gas, which openings are only large enough for a single molecule to pass at once, they would be able, without expenditure of energy, to open and close the openings in such a way as to allow each molecule impinging at an opening to pass through or not, as they should choose. If they permitted only those molecules having more than the mean *vis viva* to pass in one direction, and only those having less than the mean to pass in the opposite direction, then the gas in one side of the diaphragm would gain energy at the expense of that on the other side. That this process is actually at present beyond human ability, does not show that we may not at some future time be able to accomplish what Maxwell proposed. If this be admitted, then the conclusions which I shall draw later from the lack of generality in the second law of thermo-dynamics flow to a limited extent from the possibility of this process. But Maxwell's process assumes the kinetic theory of gases as its basis, and stands or falls with it. And if the second law is a necessary ultimate mechanical principle, holding for all bodies great and small, the above consequence of the kinetic theory of gases being in contradiction to the second law, is fatal to the validity of the kinetic theory. But I do not now so regard the second law. I am compelled to regard it as merely an approximation in the case of radiations, and to regard it in general with Maxwell and with Boltzmann,* as merely

*Wien. Sitzb., Bände LXXVI, LXXVIII.

the mean result flowing from the laws of propability, though it had previously seemed to me possible to show it to depend upon fundamental considerations, respecting the nature of heat as a form of energy as was stated in my work previously referred to.

To advert to the consequences which are thus made to flow from the established fact of the finite velocity of radiant heat, we may mention that if the law of the dissipation of energy is no longer to be regarded as of universal validity, it being obviated by the process of the syren, it is just as possible to avail ourselves of the heat stored in cold bodies as in hot ones, and thus to employ the heat of a glacier to drive a steam engine, or to perform other like feats heretofore regarded as impossibilities. When I say it is just as possible, I do not imply that it is now just as practicable, or perhaps, ever will be so. That these observations are just is seen when we reflect that the process of the syren simply heats a given body at the expense of any other, regardless of temperatures, by a method requiring the expenditure of no energy. It thus appears that it is possible to avail ourselves of the heat existing in bodies below the lowest thermometric levels of surrounding objects.

It may be objected that the syren renders a perpetual motion a possibility. That depends upon the definition of perpetual motion which we adopt. In the popular acceptation of that term, the process of the syren, as well as that of Maxwell, would make something near that possible. But when correctly viewed, the process of the syren does not imply the possibility of a perpetual motion, any more than does combustion or using the available energy of any chemical process. It simply proposes to employ the finite amount of energy existing in a given body, in the form of heat, in a given way.

It is admitted by all that heat could—a part of it—be made to do work by parting with some of it to a cooler body. The question is whether this last part, which has been imparted to a cooler body, can be restored or transferred to the warmer body again without the expenditure of energy. Rankine evidently believed such a transfer possible; for, in a paper on the "Reconcentration of the Mechanical Energy of the Universe,"[1] he has supposed it possible to reflect radiations in such a way as to give the universe such differences of temperature as to insure it a new lease of life. Clausius, in his admirable paper on the "Concentration of Rays of Light and heat,"[2] has shown

[1]Philosophical Magazine (4) 4, 358.

[2]Mechanical Theory of Heat, Chapter XII.

the general impossibility of such a reconcentration as Rankine supposed, when the radiating bodies are at rest; nevertheless, no such impossibility may finally appear in case of the actual universe, which is a system of moving bodies.

The law of the dissipation of energy has been applied to the universe at large, and if the consequences which have been drawn from its supposed validity are to be regarded as no longer expressing a necessary law, then we are led to affirm that without a change in the laws of nature, as at present known to us, it is possible for increasing differences of temperature to be caused without the expenditure of energy, however improbable the supposition may be that such is the fact, and however improbable it may be that such differences are actually being caused on a scale sufficient to interfere in any practical way with the progress of the dissipation of energy, as affirmed by Thomson, or check the increase of the entropy of the universe, as stated by Clausius. Still it may be remarked that a large part of the exchange of heat in the universe takes place in the radiant form; and, it seems to me, that it remains to be proved what the fact actually is, and consequently I must regard it as still an open question, as to whether on the whole the available energy of the universe is being dissipated, and its entropy increases or not.

Lest the foregoing remarks should be construed as in any sense undervaluing the splendid discoveries of Clausius, Thomson, and Rankine in the domain of thermo-dynamics, let me disclaim such an interpretation entirely, and say that my only wish is to add, if possible, to the exactness and completeness of those theories, which are among the most important of modern physics.—University of Cincinnati, *April 22, 1882.*

Note.—Professor J. Willard Gibbs has suggested to me that we are not at liberty to assume that reflections or radiations taking place at moving surfaces follow the same laws as from surfaces at rest; and that a perfect reflector, moving in a medium through which luminous waves are being propagated, may suffer a resistance which would require the expenditure of as much energy as could be obtained by the proposed process. Admitting for the moment the justness of these observations respecting reflections and radiations from moving surfaces, I shall hope to show, in the first place, that the syren may be so adjusted that no such resistance need be encountered, and in the second place, that it is possi-

ble so to modify the syren that no reflections or radiations need take place from moving surfaces.

In the discussion of the first point, let us consider the case of a ray falling perpendicularly upon a perfect reflector. The only numerical magnitudes susceptible of variation in this radiation are its wave length and amplitude, the velocity being assumed constant and dependent upon the elasticity of the medium. When the reflector moves in its own plane at right angles to the ray, it cannot, apparently, be seriously urged that the reflected ray will have either its wave length or its amplitude changed by the reflection. For, so far as can be seen, the wave length would suffer a change and be shortened only by giving the reflector a motion toward the approaching ray, thus crowding the waves together. Neither would the amplitude be changed, for to do this would require the moving plane to impart tangential impulses to the ether, such as can be compounded with the transverse motions already existing. If such be the tangential action of the moving plane on the ether, we should be led to the apparently inadmissible result, that since a moving plane may impart tangential impulses to the luminferous ether, a disk rotating with sufficient velocity in vacuo would become self-luminous.

It would seem but reasonable, in our present imperfect knowledge of the subject, to conclude that the only resistance which a perfect reflector experiences while moving against a ray is normal to its surface, and to be represented by a normal pressure. Even if this view be not regarded as entirely correct, it may, nevertheless, be confidently affirmed that the tangential must be small compared with the normal resistance, just as a frictional resistance of a gas is small compared with that arising from direct pressure upon a body moving through it. Hence it is seen that in spite of friction, it is possible to make a ray turn a mill whose vanes are perfect reflectors, in the same manner as the wind turns a wind-mill; and the energy expended will in that case be withdrawn from the ray itself. Now the rotating screen c of the syren may be regarded as such a mill, the surfaces of whose vanes may be so inclined as to return radiations coming from B, partly to apertures in front of those from which they emanated, and partly to those behind, so as to exert no force either to accelerate or retard c. Should, however, energy be expended in moving c against the reflected ray, this energy must exist immediately after the reflection in the reflected ray, and be transmitted by it to B. Hence we are led to the following remarkable result: On the hypothesis that radiations cause

pressure at surfaces at which they suffer total reflection, a part of the energy of the radiation may be expended in moving the reflector against a resistence, while the remainder is all reflected to the body from which it emanated. It is to be noticed that this process of the *reflecting mill*, or *mill* as it may be called for brevity, is, if possible, in more pronounced and unequivocal contradiction to the second law than that of the syren. For the latter calls in question the accepted law of mutual exchanges, and the second law as depending upon it; but the former applies to a single body alone, as *B*, and a moving reflector. For example, let *B* have no radiations except those through the apertures *b;* then if that part of its radiations which are not expended in turning *c* are returned to it, it is possible for the mill *c* to be turned by radiations from *B*, until the energy of *B* is all expended in performing work, thus withdrawing all heat from *B*, while no heat has been transferred to any other body in the manner required by the second law, and this regardless of the temperature of surrounding objects. It therefore seems to me that the supposition of a pressure at reflecting surfaces is more directly opposed to the second law than that of no pressures.

In regard to the second point mentioned, it seems quite possible to construct a syren such that the reflections in it shall all take place from stationary surfaces, or from those whose velocity differs from zero by less than any assignable quantity. For, let the mean velocity *u* of the screens be the same as before, but not continuous. Instead, let its motion consist of sudden steps forward, each of which is half the width of an aperture. The possibility of a mechanical arrangement, which could effect this motion without expenditure of energy, with the aid of perfect springs, fly-wheels, detents, etc., to any required degree of approximation, will, I think, be admitted, certainly by any one who can admit that Maxwell's "sorting demon" expends no energy in opening and closing apertures. It will be seen that the reflections all take place from screens at rest (or nearly so) in this modified syren, and that the same transmissions occur through its apertures as have heretofore been supposed to take place. I am not inclined, however, to insist on the special kind of apparatus which I have proposed for rendering sensible the phenomenon which I believe to exist during the time in which radiations are in process of becoming established, as contemplated in the ordinary law of thermal exchanges. The point to which I would emphatically direct attention is, that since radiations

are known to be moving in space apart from ponderable bodies, and subject to reflections, it is possible so to deal with them as to completely alter their destination, and successfully interfere with all results flowing from Prevost's law of Exchanges. It also seems to me that the exactness of the second law of thermo-dynamics depends, as far as radiations are concerned, upon that of this law of exchanges.

Cincinnati, May 18, 1882. H. T. E.

CRANK PINS OF MARINE ENGINES.

By J. H. Whitham,
Cadet Engineer, U. S. N.

In compiling appended table, the co-efficient of friction was assumed to be 0·05. The table contains crank-pin data from the modern English and American naval and merchant vessels. In each case the engines were performing well and at full power. The *Miantonomah* is the only exception, and she has not as yet had a fair trial of her machinery, but her crank-pin should run cool, as she has an excessive margin of safety, both as regards the projected area of pin and its pressure and the work of friction per unit of area. Comparing the performances of English and American crank-pins, it is seen that the work of friction and pressure per square inch of projected area for the former exceed those of the latter; also, that no one method has been followed in designing each of them.

On page 70, Prof. Marks' treatise on "The Steam Engine," the work of friction per square inch of projected area is given as 49,908 inch-pounds, while in the cases illustrated in table appended, the work is $12 \times 3{,}309{\cdot}9 = 39{,}718{\cdot}8$ inch-pounds, or a margin of area over 10 per cent. If, however, the averages of the best ten performances shown in the table are taken, we have work of friction per square inch projected area equal to $12 \times 5{,}086{\cdot}6 = 61{,}039{\cdot}2$, or the margin is exceeded by over 10 per cent.

The practice recommended in designing crank-pins is to deduce the length as shown in § 30 of Prof. Marks' treatise on "Steam Engine," and then the diameter as illustrated in §§ 32, 33. A check to the result thus obtained is illustrated in the following formula, in which c = coefficient of friction of rubbing surfaces; v = velocity of rub-

bing surfaces in feet per minute; p = effective pressure on each square inch of piston area; A = square inches of area of piston; l = length of pin, and d = diameter of pin, each in inches; then the heat units are

$$(1) \quad \frac{60p.Avc}{772} = 250ld \text{ or } ld = 0{\cdot}000015545p.Av, \text{ when } c = 0{\cdot}05.$$

To illustrate the problem of the crank-pin dimensions, take the case of the *Galena*, whose crank-pin is $18\frac{1}{2}$ inches long and $10\frac{1}{2}$ inches in diameter.

By formula (81) § 30 of "Steam Engine," by Prof. Marks, length of pin = $0{\cdot}0000247 \times 0{\cdot}05 \times 130 \times 64 \times 64 = 8{\cdot}088$ inches.

By formula (85) § 34,

$$\text{diameter of pin} = \frac{0{\cdot}00157 \times 64 \times 64 \times 12{\cdot}3}{8{\cdot}088} = 10\tfrac{1}{4} \text{ inches.}$$

By formula (1) above,

$$\text{length of pin} = \frac{0{\cdot}000015545 \times 39890 \times 178{\cdot}7}{10{\cdot}5} = 10{\cdot}55$$

If in formula (1) 387 is used in the place of 250 (see table), the

$$\text{length of pin} = \frac{60 \times 39890 \times 178{\cdot}7 \times 0{\cdot}05}{772 \times 387 \times 10{\cdot}5} = 7 \text{ inches (nearly).}$$

In § 44 of "Friction and Lubrication," by Prof. Thurston, the temperature of vaporization of lubricating oils is given as 600°F., and on page 78 is the following table:

Oil.	Flash.	Takes fire.	Burns.
Winter sperm,	425°F.	485°F.	500°F.
Lard,	475°	525°	525°

All of which shows that the temperatures of vaporization of oils, and not the point of fusibility of the metals, are to be considered in designing crank-pins. Now if the rates of transmission of heat through various metals, as determined by Chief Engineer Isherwood (see page 57 of Shock's "Steam Boilers"), are taken as practically correct for crank-pins, in the most aggravated case, the high-pressure cylinder of the *Rover*, the temperature of the pin, if properly lubricated, should not be increased over 2° in temperature. But as no experiments have ever been made to determine the temperature of the crank-pin brasses, we are forced to adopt existing methods of design.

U. S. S. *Galena*, Montevideo, Uraguay, December 6, 1882.

ON THE APPLICATION OF THE PRINCIPLE OF VIRTUAL VELOCITIES TO THE DETERMINATION OF THE DEFLECTION AND STRESSES OF FRAMES.

By George F. Swain, S.B.
Instructor of Civil Engineering in the Massachusetts Institute of Technology, Boston, Mass.

(Continued from page 115.)

IV. The Arch Hinged at Crown (Fig. 8).

This case, though of no practical importance, is here introduced simply for the sake of completeness. Two conditions must be sought from the theory of elasticity in order to find the reactions. The third is that the moment at the hinge is zero, or that the resultant R, of the loads and reactions on either side of the hinge, must pass through the

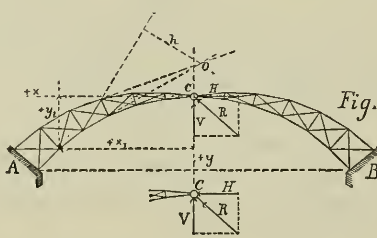


Fig. 8

hinge. Let us resolve R, the resultant on the right, into its horizontal and vertical components, V and H. It is clear that if we find the values of V and H we have solved the problem, because then R is known, and we can compound it with the loads on either side of the hinge, and so find either reaction. Let V and H be called positive when they act in the directions given in the figure, that is, when the vertical component of the resultant of the forces on the right of the hinge acts upward, and the horizontal component of this resultant acts toward the left. For greater clearness, let us denote by subscript r and l when the forces R, V, and H, refer to the right-hand or left-hand halves of the arch. Now, if we replace the right-hand half by R_r, the forces applied to the left-hand half (including R_r) will cause a certain horizontal and vertical deflection of the point C, each of which we can easily calculate, in terms of V and H, which are unknown.

Similarly, for the right-hand half of the arch we can calculate the deflection of C in each direction. The two conditions necessary to solve the problem are clearly these: that the horizontal deflection of C for each half shall be equal in amount, and that the same shall be true for the vertical deflection of C. We have, then, to find values for these deflections, and to place them equal to each other. We proceed as follows: call v_1 the stress produced in any bar of the left-hand bar by a force equal to unity, acting *downward* at C; h_1 that produced by a unit force acting in the same point horizontally *toward the right.* Let the stress produced in the same bar by the applied loads—considered as the only forces acting on the left-hand half, the right-hand half being removed—be s_1; that produced by H, x_1; and that produced by V, y_1. Then we have

$$x_1 = - H\, h_1 : \; Y_1 = - V\, v_1.$$

The real stress in the bar is $s_1 + x_1 + y_1 = S$.

The vertical downward deflection of C, the left-hand half only being considered, is

$$\begin{aligned} \Delta_v &= \Sigma_1\, v_1 \frac{s_1 \,.\, l}{FE} + \Sigma_1\, v_1 \frac{x_1 \,.\, l}{FE} + \Sigma_1\, v_1 \frac{y_1 \,.\, l}{FE} \\ &= \Sigma_1 \frac{v_1\, s_1 \,.\, l}{FE} - H\, \Sigma_1 \frac{v_1\, h_1\, l}{FE} - V\, \Sigma_1 \frac{v_1^2\, l}{FE}, \end{aligned} \tag{14}$$

the summations being extended over the left-hand half.

Similarly, the horizontal deflection of C to the right, considering only the left-hand half, is

$$\begin{aligned} \Delta_h &= \Sigma_1\, h_1 \,.\, \frac{s_1\, l}{FE} + \Sigma_1\, h_1 \,.\, \frac{x_1\, l}{FE} + \Sigma_1\, h_1 \,.\, \frac{y_1\, l}{FE} \\ &= \Sigma_1 \frac{h_1\, s_1\, l}{FE} - H\, \Sigma_1 \frac{h_1^2\, l}{FE} - V\, \Sigma_1 \frac{h_1\, v_1\, l}{FE}. \end{aligned} \tag{15}$$

By considering the right-hand half alone, we get the following two equations: for the vertical downward deflection,

$$\Delta'_v = \Sigma_r \frac{v_r\, s_r\, l}{FE} + H\, \Sigma_r \frac{v_r\, h_r\, l}{FE} + V\, \Sigma_r \frac{v_r^2\, l}{FE}; \tag{16}$$

and for the horizontal deflection towards the right,

$$\Delta'_h = \Sigma_r \frac{h_r\, s_r\, l}{FE} + H\, \Sigma_r \frac{h_r^2 \,.\, l}{FE} + V\, \Sigma_r \frac{h_r\, v_r\, l}{FE}. \tag{17}$$

The two conditions given by the theory of elasticity are, therefore: $\Delta_v = \Delta'_v$, and $\Delta_h = \Delta'_h$, or

$$\Sigma_1 \frac{v_1 s_1 l}{FE} - H \Sigma_1 \frac{v_1 h_1 l}{FE} - V \Sigma_1 \frac{v_1^2 l}{FE}$$

$$= \Sigma_r \frac{v_r s_r l}{FE} + H \Sigma_r \frac{v_r h_r l}{FE} + V \Sigma_r \frac{v_r^2 l}{FE}. \qquad (18)$$

$$\Sigma_1 \frac{h_1 s_1 l}{FE} - H \Sigma_1 \frac{h_1^2 l}{FE} - V \Sigma_1 \frac{h_1 v_1 l}{FE}$$

$$= \Sigma_r \frac{h_r s_r l}{FE} + H \Sigma_r \frac{h_r^2 l}{FE} + V \Sigma_r \frac{h_r v_r l}{FE}. \qquad (19)$$

These equations become simple when numerical values are inserted, and from them V and H can be found, being the only unknown quantities. The remainder of the discussion regarding this form of arch does not belong here.

We may note briefly, however, a transformation similar to that given for the previous case. Equation (18) may be written

$$\Sigma_1 \frac{v_1 S l}{FE} = \Sigma_r \frac{h_r S l}{FE}, \qquad (20)$$

and equation (19) $\Sigma_1 \frac{h_1 S l}{FE} = \Sigma_r \frac{h_r S l}{FE}. \qquad (21)$

Considering always a moment M as positive when the resultant force on the left of a given section has a right-handed moment with reference to the origin of moments, we may write

$$S = \frac{M}{h}\,;\ v_1 = -\frac{x_1}{h}\,;\ h_1 = -\frac{y_1}{h}\,;\ v_r = \frac{+x_r}{h} \quad h_r\,; = \frac{+y_r}{h}\,;$$

h being always put in with its proper sign, so that when M and h are both positive, the stress is a tension.

In these equations C is taken as the origin of co-ordinates, with x positive to the left and y positive downwards, the co-ordinates x_1, y_1, x_r, y_r, being those of the origin of moments for the bar in question. Substituting these values in (20) and (21), we have,

$$\Sigma_1 \frac{M x_1 l}{EF h^2} = -\Sigma_r \frac{M x_r l}{EF h^2}. \qquad (22)$$

$$\Sigma_1 \frac{M y_1 l}{EF h^2} = -\Sigma_r \frac{M y_r l}{EF h^2}. \qquad (23)$$

Neglecting the web members, these equations reduce approximately to the following, as a little consideration will show:

$$\Sigma \frac{Mxl}{I} = o. \tag{24}$$

$$\Sigma \frac{Myl}{I} = o. \tag{25}$$

equations analogous to those given for solid ribs, viz:

$$\int \frac{Mxds}{I} = o\ ; \int \frac{Myds}{I} = o.$$

The signs of the various quantities considered must be carefully borne in mind in forming their sums. For the purposes of this article this need not be enlarged upon.

V. The Arch Without Hinges.

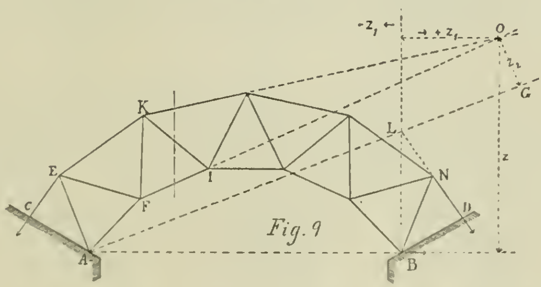


Fig. 9

We approach now the last case of frames supported at two points, and the most difficult case of all. Three conditions have to be supplied by the theory of elasticity. Those given for solid arches are, that the vertical and horizontal deflections of one end, with reference to the other, are zero, and that the ends remain fixed in direction,—conditions reducing to three independent equations. In the case of frames, various methods of treatment are possible. The following is due to Winkler.

Supposing three bars to start from each abutment, we can replace the unknown reactions by the stresses in these bars, so that we have six unknown quantities. Suppose, also, that the bars at the abutments are as in the figure. We take the point A as immovable, B as sliding (for the present) on a horizontal surface, so that we consider the frame as supported at two points, by vertical reactions. We can calculate now, under this supposition, the stress S_v, in any bar IK, due to the given vertical loads, and also the stresses s, s_1, and s_2, in IK, due to a load unity

acting outward respectively in B (along AB), in C (along EC), and in D (along ND). Call the *real* forces acting in these points, H (acting inward, along BA), R_1 (acting inward, along CE), and R_2 (acting inward, along DN). Then the real stress in IK is S_v—sH—$s_1\,R_1$—$s_2\,R_2$. The horizontal deflection of B, outward, is

$$\Delta_b = \Sigma \frac{s\,S_v\,l}{EF} - H\,\Sigma\frac{s^2\,l}{EF} - R_1\Sigma\frac{s\,s_1\,l}{EF} - R_2\,\Sigma\frac{s\,s_2\,l}{EF}. \qquad (26)$$

The outward deflection of C is also clearly,

$$\Delta_c = \Sigma \frac{s_1\,S_v\,l}{EF} - H\,\Sigma\frac{s_1\,s\,l}{EF} - R_1\Sigma\frac{s_1{}^2 l}{EF} - R_2\,\Sigma\,\frac{s_1 s_2\,l}{EF}, \qquad (27)$$

and that of D is

$$\Delta_d = \Sigma \frac{s_2\,S_v\,l}{EF} - H\,\Sigma\frac{s_2\,s\,l}{EF} - R_1\Sigma\frac{s_2 s_1 l}{EF} - R_2\,\Sigma\,\frac{s_2{}^2 l}{EF}. \qquad (28)$$

Each of these quantities, however, must be zero, if the points A, B, C, D, are immovably fixed, so that we have at once the three equations of condition.

$$\Delta_b = o\,;\ \ \Delta_c = o\,;\ \ \Delta_d = o.$$

From these three equations we can find H, R_1, and R_2. The three statical conditions of equilibrium enable us then to find the vertical reaction in B, and the reaction in A.

We may write the three conditions of equilibrium as follows:

$$\Sigma\,\frac{s.S.l}{EF} = o\,;\qquad \Sigma\,\frac{s_1.S.l}{EE} = o\,;\qquad \Sigma\,\frac{s_2.S.l}{EF} = o,$$

or $\qquad \Sigma\, s.\,\Delta l = o\,;\qquad \Sigma\, s_1.\,\Delta l = o\,;\qquad \Sigma\, s_2.\,\Delta l = o.$

S being the real stress in any bar, and Δl its elongation. As before, we have $S = \frac{M}{h}$. If we draw BL vertical, and call L its intersection with the bar DN, we can also put $s = \frac{+z}{h}$, where z = distance of O above AB, the point O being the origin of moments for any bar. Further, a unit force outward, in C causes a downward reaction in B, which we call d; if z_1 denotes the distance of O to the right of BL, we have the moment about O of the forces to the right of the section equal to $x\ \dot{z}_1$, and negative; hence $s_1 = \frac{+dz_1}{h}$. An outward force equal to unity in D causes a vertical reaction in B, and an outward reaction in A along LA, which we call d^1. If, therefore, O be above AL, and $OG = z_2$, we have $s_2 = \frac{+\,d^1 z_2}{h}$. These stresses, it will be

remembered, are those in the bar IK, due to unit load in B, C, and D. d and d^1 are constants.

Substituting these values, we have

$$\Sigma \frac{z\,M\,l}{F\,h^2} = o; \quad \Sigma \frac{z_1\,M\,l}{F\,h^2} = o; \quad \Sigma \frac{z_2\,M\,l}{F\,h^2} = o.$$

If we take two rectangular axes, X and Y, in the plane of the frame, we can express z, z_1 and z_2, as follows, in terms of x and y, the co-ordinates of the point O.

$$z = a + b\,x + c\,y; \; z_1 = a_1 + b_1\,x + c_1\,y; \; z_2 = a_2 + b_2\,x + c_2\,y.$$

Substitute these values, and we have

$$a\,\Sigma \frac{M\,l}{Fh^2} + b\,\Sigma \frac{x\,M\,l}{F\,h^2} + c\,\Sigma \frac{y\,M\,l}{F\,h^2} = o. \tag{29}$$

$$a_1\,\Sigma \frac{M\,l}{Fh^2} + b_1\,\Sigma \frac{x\,M\,l}{F\,h^2} + c_1\,\Sigma \frac{y\,M\,l}{F\,h^2} = o. \tag{30}$$

$$a_2\,\Sigma \frac{M\,l}{Fh^2} + b_2\,\Sigma \frac{x\,M\,l}{F\,h^2} + c_2\,\Sigma \frac{y\,M\,l}{F\,h^2} = o. \tag{31}$$

These equations give the following,

$$\Sigma \frac{M\,l}{Fh^2} = o; \quad \Sigma \frac{x\,M\,l}{F\,h^2} = o; \quad \Sigma \frac{y\,M\,l}{F\,h^2} = o; \tag{32}$$

and these equations bear some analogy to those sometimes given for solid arches, namely,

$$\int \frac{M\,ds}{I} = o; \quad \int \frac{M\,x\,ds}{I} = o; \quad \int \frac{M\,y\,ds}{I} = o,$$

provided we neglect the influence of the web members.

The further discussion of the best methods of applying these equations would occupy too much space, and we must refer to Winkler's original article.*

We have now seen how the method which we have explained is applied to arches. It remains, before taking leave of cases where the outer forces are statically undetermined, to discuss the one remaining case of importance, viz., the continuous girder.

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* Winkler. Beitrag zur Theorie der Bogenträger Zeitschr. d. Archit. & Ing. Vereins zu Hannover. 1879. Page 199.

VI. The Continuous Girder (Fig. 10).

Consider a continuous girder of n spans, their lengths being l_1, l_2, l_3, —— l_n. Let the reactions be R_1, R_2, R_3, —— R_{n+1}; and let the total length, $l_1 + l_2 + l_3 +$ —— l_n, $= L$. Supposing the reactions to be

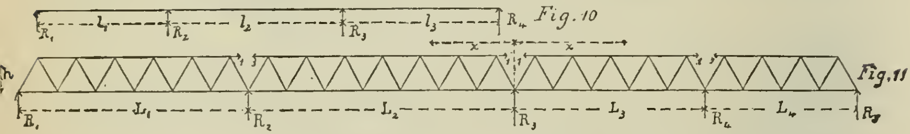


Fig. 10

Fig. 11

all vertical but one, and applied at given points, and the loads vertical or inclined, we have $n + 2$ unknown quantities, one at each point of support where the reaction is vertical, and two at the remaining point of support. Statics affords only three equations, so that there are $n - 1$ equations to be obtained from the theory of elasticity. These are given by the conditions of the supports, and taking the line joining the end supports as an axis, we have to express that at each intermediate support the deflection is zero or a given quantity. We then obtain $n - 1$ equations, and can solve the problem. The resulting equations are the following: Let h_2, h_3, etc., be the deflections of the intermediate supports *below* the line joining the end supports. Let S be the actual stress in any bar, l its length, E its modulus of elasticity, and F its cross section; let t_2 be the stress caused in it by a load unity acting *downward* at the second point of support, t_3 that caused by an equal load at the third, t_4 that at the fourth—all calculated as though the girder were simple, and had a length, L. Let the stress caused in the bar by the given load acting on the girder, calculated as a beam of length, L, be s. Then the real stress S, in any bar, is

$$S = s - t_2 R_2 - t_3 R_3 - t_4 R_4 \cdots\cdots - t_n R_n \qquad (33)$$

and the conditions which we have are

$$\left.\begin{array}{l} h_2 = \sum_0^L t_2 \dfrac{S\,l}{EF} \\ h_3 = \sum_0^L t_3 \dfrac{S\,l}{EF} \\ h_4 = \sum_0^L t_4 \dfrac{S\,l}{EF} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ h_n = \sum_0^L t_n \dfrac{S\,l}{EF} \end{array}\right\} \qquad (34)$$

These equations may also be written as follows:

$$\left.\begin{aligned}
h_2 &= \sum_0^L t_2 \frac{s\,l}{EF} - R_2 \sum_0^L \frac{t_2^2\,l}{EF} - R_3 \sum_0^L t_2 \frac{t_3\,l}{EF} - \\
&\quad R_4 \sum_0^L t_2 \frac{t_4\,l}{EF} \cdots\cdots - R_n \sum_0^L t_2 \frac{t_n\,l}{EF} \\
h_3 &= \sum_0^L t_3 \frac{s\,l}{EF} - R_2 \sum_0^L t_3 \frac{t_2\,l}{EF} - R_3 \sum_0^L t_3^2 \frac{l}{EF} \\
&\quad - R_4 \sum_0^L t_3 \frac{t_4\,l}{EF} \cdots\cdots - R_n \sum_0^L t_3 \frac{t_n\,l}{EF} \\
h_4 &= \sum_0^L t_4 \frac{s\,l}{EF} - R_2 \sum_0^L t_4 \frac{t_2\,l}{EF} - R_3 \sum_0^L t_4 \frac{t_3\,l}{EF} - \\
&\quad R_4 \sum_0^L t_4^2 \frac{l}{EF} \cdots\cdots R_n \sum_0^L t_4 \frac{t_n\,l}{EF} \\
h_n &= \sum_0^L t_n \frac{s\,l}{EF} - R_2 \sum_0^L t_n \frac{t_2\,l}{EF} - R_3 \sum_0^L t_n \frac{t_3\,l}{EF} \\
&\quad - R_4 \sum_0^L t_n \frac{t_4\,l}{EF} \cdots\cdots - R_n \sum_0^L \frac{t_n^2\,l}{EF}
\end{aligned}\right\} \tag{35}$$

These equations are $n - 1$ in number, and the only unknown quantities are the $n - 1$ reactions, R_2 ...... R_n, These once obtained, the problem is solved. We shall refer again to another solution of the continuous girder, by which equations are obtained which may be easily reduced to those obtained by the theorem of three moments.

VII. Trusses with Superfluous Bars.

We consider here the case of plane systems which are statically undetermined regarding the inner forces, and in which the number of equations is less than the number of unknown quantities, or in which $2m - 3 < n$. To solve such a system, the following is our method of procedure:

Suppose at any two joints A and B of the frame, forces equal to unity to act, along AB, and towards each other. These forces will, in general, cause reactions at the point of support, and stresses in the bars. Let the stress caused in any bar CD be called u, and let Δl be the change in length of the bar CD and Δp that of the line AB. Then, according to the principle of virtual velocities, supposing all the bars to be unelastic except CD.

$$1.\ \Delta p = u\ \Delta l \tag{36}$$

Δp and Δl being the absolute changes of length, without reference to sign. If, now, all the bars are elastic

$$\Delta p = \Sigma\, u\, \Delta l \tag{37}$$

In a system such as we are considering, if we omit $n - 2m + 3$ bars, we can make the system statically determined, by properly choosing the bars to be omitted, which may be called *superfluous*, while those remaining may be called *necessary*. Now, in place of one of the superfluous bars AB, let us apply at the joints where it is connected, acting towards each other (and hence representing tension in the bar) forces equal to unity. Let us use the following notation:

$\lambda_1, \lambda_2, \lambda_3$, etc. = length of the superfluous bars.

l_1, l_2, l_3, etc. = length of the necessary bars.

u_1', u_2', u_3', etc. = stresses caused in the bars of the now statically determined system by the unit forces along AB, as above described.

$\Delta l_1, \Delta l_2, \Delta l_3$, etc. = changes of length of the necessary bars, under these conditions.

Then we have, for the shortening of AB,

$$\Delta\lambda_1 = \Sigma u'\, \Delta l \tag{38}$$

Further, let

Y_1, Y_2, Y_3, etc. = stresses produced in the now statically determined system (in the necessary bars) by the given outer forces acting on the frame. These may be found by the principles of statics alone.

S_1, S_2, S_3, etc. = real stresses in the necessary bars as parts of the statically undetermined system, *i.e.*, when the superfluous bars are present.

S', S'', S''', etc. = the real stresses in the superfluous bars.

u_1'', u_2'', u_3'', etc. = stresses produced in the bars of the statically determined system (the superfluous bars being removed) by the force unity at each end of some other of the superfluous bars, $A'\,B'$, acting towards each other (tension).

u_1''', u_2''', u_3''', etc. = similar stresses produced by unit forces along another superfluous bar $A''\,B''$, etc.

Then we have clearly,

$$\left.\begin{aligned} S_1 &= Y_1 + u_1'\,S' + u_1''\,S'' + u_1'''\,S''' + \quad - \quad —— \\ S_2 &= Y_2 + u_2'\,S' + u_2''\,S'' + u_2'''\,S''' + \quad - \quad —— \\ S_3 &= Y_3 + u_3'\,S' + u_3''\,S'' + u_3'''\,S''' + \quad - \quad —— \end{aligned}\right\} \tag{39}$$

etc., etc.

In these equations Y_1, Y_2, Y_3, u_1', u_2', u_3', etc., may be determined by the elementary principles of statics, while S_1, S_2, S_3, S', S'', S''', etc., are yet unknown.

Let us now denote as follows:

f_1, f_2, f_3, etc. = sections of the necessary bars.

f', f'', f''', etc. = sections of the superfluous bars.

E_1, E_2, E_3, etc. = moduli of elasticity of the necessary bars.

E', E'', E''', etc. = moduli of elasticity of the superfluous bars.

Δl_1. Δl_2, Δl_3, etc. = real changes of length of the necessary bars.

$\Delta\lambda_1$, $\Delta\lambda_2$, $\Delta\lambda_3$, etc. = real changes of length of the superfluous bars.

Then we have

$$\left.\begin{aligned} \Delta l_1 &= \frac{l_1 S_1}{E_1 f_1} = K_1 \ S_1, \text{ if } \frac{l_1}{E_1 . f_1} = K_1 \\ \Delta l_2 &= \frac{l_2 S_2}{E_2 f_2} = K_2 \ S_2, \text{ if } \frac{l_2}{E_2 f_2} = K_2 \end{aligned}\right\} \quad (40)$$

Similarly,

$$\Delta l_3 = K_3 \ S_3 \, ; \ \Delta l_4 = K_4 \ S_4, \text{ etc.}$$

$$\Delta\lambda_1 = K' \, S' ; \ \Delta\lambda_2 = K'' \, S'' ; \ \Delta\lambda_3 = K''' \, S''', \text{ etc.}$$

If we always call tension positive and compression negative, the change of length will be positive when the length is increased, and negative when it is diminished. If we find the value of $u' \ \Delta l_1$ in equation (38), it will be always positive, for u' and Δl_1 will be both positive or both negative. In that equation, however, Δl_1 was the change of length produced in one of the necessary bars by a unit tension in one of the superfluous bars, AB. Expressed in words, that equation states that if we multiply the change of length, Δl, of each necessary bar, by the stress produced in it by unit forces along AB, acting towards each other, the sum of the values so found will be the *shortening* of AB; and this will be the case if we only insert for Δl the real change of length, from whatever cause. If the points A and B, however, are connected by the superfluous bar AB, the shortening of AB is $- K' \ S'$, tension being positive. Substitute now in equation (38) the values of $\Delta\lambda_1$ and Δl, and we have the first of the following equations.

$$\left.\begin{aligned} -K'\ S' &= u_1'\ K_1\ S_1 + u_2'\ K_2\ S_2 + u_3'\ K_3\ S_3 + \ldots\ldots \\ -K''\ S'' &= u_1''\ K_1\ S_1 + u_2''\ K_2\ S_2 + u_3''\ K_3\ S_3 + \ldots\ldots \\ -K'''\ S''' &= u_1'''\ K_1\ S_1 + u_2'''\ K_2\ S_2 + u_3'''\ K_3\ S_3 + \ldots\ldots \end{aligned}\right\} \quad (41)$$

Finally, substituting for S_1, S_2, S_3, etc., their values from (39) we have

$$\left.\begin{aligned} K'\,S' = &-u_1'\,K_1\left(Y_1 + u_1'\ S' + u_1''\,S'' + u_1'''\ S''' + \ldots\ldots\right) \\ &-u_2'\,K_2\left(Y_2 + u_2'\,S' + u^{2''}\ S' + u_2'''\ S''' + \ldots\ldots\right) \\ K''\ S'' = &-u_1''\,K_1\left(Y_1 + u_1'\,S' + u_1''\,S'' + u_1'''\,S''' + \ldots\ldots\right) \\ &-u_2''\,K_2\left(Y_2 + u_2'\ S' + u_2''\ S'' + u_2'''\ S''' + \ldots\ldots\right) \end{aligned}\right\} \quad (42)$$

These may be transformed to the following:

$$\left.\begin{aligned} &S'\,(K' + u_1'\,u_1'\,K_1 + u_2'\,u_2'\,K_2 + \ldots\ldots) + S''\,(u_1'\ u_1''\ K_1 \\ &\quad + u_2'\,u_2''\,K_2 + \ldots\ldots) + S'''\,(u_1'\,u_1'''\ K_1 + u_2'\,u_2'''\,K_2 + \\ &\quad \ldots\ldots) + u_1'\,K_1\,Y_1 + u_2'\,K_2\,Y_2 + \ldots\ldots = o \\ &S'\,(u_1'\,u_1''\,K_1 + u_2'\,u_2''\,K_2 + \ldots\ldots) + S''\ (K'' + u_1''\,u_1'' \\ &\quad K_2 + u_2''\,u_2''\,K_2 + \ldots\ldots) + S'''(u_1''\,u_1'''K_1 + u_2''\,u_2'''K_2 + \\ &\quad \ldots\ldots) + u_1''\,K_1\,Y_1 + u_2''\,K_2\,Y_2 + \ldots\ldots = o. \end{aligned}\right\} \quad (43)$$

These equations are equal in number to the superfluous bars. From them, therefore, the unknown stresses S', S'', S''' etc. may be determined, after which the stresses S_1, S_2, S_3, etc., may be found from equations (39).

This method, which appears complex when treated in its general form, becomes simple when applied to any particular case, if the calculation is made methodically, and the results arranged in tabular form. It is scarcely necessary to exemplify its application. Statically undetermined systems should be avoided by the constructor when practicable, except in some cases where they afford practical advantages sufficient to more than balance the uncertainty in the calculation by ordinary methods.

(To be continued.)

DESCRIPTION OF AN ELECTRIC SIGNAL CLOCK.

By Aaron D. and Geo. W. Blodgett.

[A paper read at the stated meeting of the Franklin Institute, December 20, 1882.]

The requirements of business at the terminus of a railway of any considerable magnitude necessitates the arrival and departure of a large number of trains.

The development of the country through which it passes, and the increased traffic which is the consequence thereof, call for constant addition to its facilities for the safe and convenient transportation of passengers.

The problem of dispatching fifty, sixty, or a hundred trains per day with promptness and regularity has become so important that only the most reliable men are considered competent for this work. But with the utmost care, mistakes are made and delays occur which are detrimental to the business of the road, and endanger the lives of its patrons.

The usual method of giving signals for the departure of railway trains is to put the signal bells in charge of the ticket agent, who, besides answering questions, selling tickets, and making change, gives signals for the trains to depart, as well as the usual preliminary signals.

It is not at all surprising that, as is always found to be the case, much irregularity exists in the time of the signals; that at the critical moment something else often engages the operator's attention, and the signal is delayed and sometimes forgotten; or in the effort to start trains promptly, it is given too early and the train departs before it should.

Careful observation shows that errors of this kind will happen with the most painstaking men, and even in cases where the operator's only business is to dispatch trains, the inaccuracy is greater than is commonly supposed.

Experience teaches that whenever machinery can be substituted for human labor, greater accuracy can be attained.

So far as we know, a machine has never yet been invented which would answer questions, sell tickets, or make change; but we are able to show a machine which will give correctly the warning and departure signals for any number of trains in their proper order.

The essential features of this machine are:—

A cylinder which is provided with a separate hole for each minute in the twenty-four hours.

A shoe, or follower, is so contrived as to pass over every hole in the cylinder once a day. This is connected with suitable circuit-closing mechanism in such a way that a slight movement of the shoe away from the cylinder, will set in operation the signaling apparatus.

Small pins are screwed into the holes which correspond in location to the times when signals should be given.

The operation of the machine, which will be readily understood, is as follows:

A standard clock (which is to be found at every railway terminus), is caused to close an electric circuit in a well-known way once each minute.

The current passes through an electro-magnet connected by a pawl to a ratchet-wheel of sixty teeth, which it advances one tooth at each closure of the circuit.

This ratchet rotates the cylinder one step each minute, which, therefore, makes one revolution in an hour.

Most railroads require two signals for the departure of every train, a warning, or preliminary, signal which precedes the other by a certain interval—two, three, or five minutes—and a starting signal sounded at the exact time when the train should depart.

Whenever the follower comes in contact with the pin corresponding to a warning signal, the circuit-closing mechanism is released, and one or more blows are struck upon the bells, according to the signal required. After the lapse of the proper interval, the follower comes in contact with the second pin, and the signal is given for the train to start.

When the time of the next train approaches the operations are repeated, and so on through the time-table.

At twelve o'clock, midnight, the follower having completed its traverse of the holes in the cylinder, is automatically transferred to the first hole of the series and begins a new day.

The cylinder is provided with an additional series of fourteen hundred and forty holes, and with pins corresponding to a Sunday timetable.

A follower also traverses the holes in this part of the cylinder, but cannot set in motion the striking mechanism during a weekday.

At midnight on Saturday the follower which could set in operation on a weekday the mechanism which strikes the bells, is disconnected, and the Sunday time-table rendered operative, striking the signals for trains on that day. At midnight, Sunday, things are restored to the first-described condition for six days more.

The instrument is, therefore, automatic in its operation, requiring only such changes as are necessary in the arrangement of pins, to correspond with changes in the time-table.

The circuit closing mechanism is driven by a spring which requires winding once a week.

A press-button and switch connected with the bells, and under control of the train-dispatcher, enables him to delay a regular signal, or to strike additional ones, should it be desired. Such interruption does not, however, in any way disarrange the apparatus, which, as soon as the switch is closed, resumes its normal operation.

One of these machines has been in use for nearly a year at the depot of the Boston and Albany Railroad, in Boston—the largest in the city—dispatching satisfactorily nearly sixty trains a day. Next in order comes the Boston and Providence Railroad, where over fifty trains a day are sent out in the same manner.

The New York and New England, and the Fitchburg Railroads follow with a less number of trains, which are also dispatched in this way.

The United States Government has recently ordered this machine for the Boston Post Office, where it signals the departure of the mails.

From the foregoing it will be seen that this instrument can be used for many other purposes besides those mentioned, such as the distribution of standard time signals for manufacturing companies, for street railroads, and for use in school-buildings; in short, wherever it is desired to sound signals for any purpose, at regular or irregular intervals.

Any conceivable arrangement of signals is also permissible, the machines in operation at the Boston depots following each a different code.

Only one change is necessary to fulfil all these conditions, and that is simple, and easily made.

The operation of setting up or changing the time-table is so simple that it can be done by any person of average intelligence, with accuracy and in a few moments.

SCIENCE IN RELATION TO THE ARTS.

By C. William Siemens, F. R. S.

(Continued from page 134)

The progressive views perceptible in the construction of the navy are further evidenced in a remarkable degree in the hydrographic department. Captain Sir Frederick Evans, the hydrographer, and Vice-President of the British Association, gave us at York last year a very interesting account of the progress made in that department, which, while dealing chiefly with the preparation of charts showing the depth of water, the direction and force of currents, and the rise of tides near our shores, contains also valuable statistical information regarding the more general questions of the physical conditions of the sea, its temperature at various depths, its flora and fauna, as also the rainfall and the nature and force of prevailing winds. In connection with this subject the American Naval Department has taken an important part, under the guidance of Captain Maury and the Agassiz, father and son, whilst in this country the persistent labors of Dr. William Carpenter deserve the highest consideration.

Our knowledge of tidal action has received a most powerful impulse through the invention of a self-recording gauge and tide-predicter, which will form the subject of one of the discourses to be delivered at our present meeting by its principal originator, Sir William Thomson; when I hope he will furnish us with an explanation of some extraordinary irregularities in tidal records, observed some years ago by Sir John Coode at Portland, and due apparently to atmospheric influence.

The application of iron and steel in naval construction rendered the use of the compass for some time illusory, but in 1839 Sir George Airy showed how the errors of the compass, due to the influence experienced from the iron of the ship, may be perfectly corrected by magnets and soft iron placed in the neighborhood of the binnacle, but the great size of the needles in the ordinary compasses rendered the correction of the quadrantal errors practically unattainable. In 1876 Sir William Thomson invented a compass with much smaller needles than those previously used, which allows Sir George Airy's principles to be applied completely. With this compass, correctors can be arranged so that the needle shall point accurately in all directions, and

these correctors can be adjusted at sea from time to time, so as to eliminate any error which may arise through change in the ship's magnetism or in the magnetism induced by the earth through change of the ship's position. By giving the compass card a long period of free oscillation great steadiness is obtained when the ship is rolling.

Sir William Thomson has also enriched the art of navigation by the invention of two sounding machines; the one being devised for ascertaining great depths very accurately in less than one-quarter the time formerly necessary, and the other for taking depths up to 130 fathoms without stopping the ship in its onward course. In both these instruments steel pianoforte wire is used instead of the hempen and silken lines formerly employed; in the latter machine the record of depth is obtained not by the quantity of wire run over its counter and brake wheel, but through the indications produced upon a simple pressure gauge consisting of an inverted glass tube, whose internal surface is covered beforehand with a preparation of chromate of silver, rendered colorless by the sea-water up to the height to which it penetrates. The value of this instrument for guiding the navigator within what he calls "soundings" can hardly be exaggerated; with the sounding-machine and a good chart he can generally make out his position correctly by a succession of three or four casts in a given direction at given intervals, and thus in foggy weather is made independent of astronomical observations and of the sight of lighthouses or the shore. By the proper use of this apparatus, such accidents as happened to the mail steamer *Mosel* not a fortnight ago would not be possible. As regards the value of the deep-sea instrument I can speak from personal experience, as on one occasion it enabled those in charge of the Cable ss. *Faraday* to find the end of an Atlantic Cable, which had parted in a gale of wind, with no other indication of the locality than a single sounding, giving a depth of 950 fathoms. To recover the cable a number of soundings in the supposed neighborhood of the broken end were taken, the 950 fathom contour line was then traced upon a chart, and the vessel thereupon trailed its grapnel two miles to the eastward of this line, when it soon engaged the cable 20 miles away from the point, where dead reckoning had placed the ruptured end.

Whether or not it will ever be practicable to determine oceanic depths without a sounding line, by means of an instrument based upon gravi-metric differences, remains to be seen. Hitherto the indications obtained by such an instrument have been encouraging, but its delicacy

has been such as to unfit it for ordinary use on board a ship when rolling.

The time allowed me for addressing you on this occasion is wholly insufficient to do justice to the great engineering works of the present day, and I must therefore limit myself to making a short allusion to a few only of the more remarkable enterprises.

The great success, both technically and commercially, of the Suez Canal, has stimulated M. de Lesseps to undertake a similar work of even more gigantic proportions, namely, the piercing of the Isthmus of Panama by a ship canal, 40 miles long, 50 yards wide on the surface, and 20 yards at the bottom, upon a dead level from sea to sea. The estimated cost of this work is 20,000,000*l.*, and more than this sum having been subscribed, it appears unlikely that political or climatic difficulties will stop M. de Lesseps in its speedy accomplishment. Through it, China, Japan, and the whole of the Pacific Ocean will be brought to half their present distance, as measured by the length of voyage, and an impulse to navigation and to progress will thus be given which it will be difficult to over-estimate.

Side by side with this gigantic work, Captain Eads, the successful improver of the Mississippi navigation, intends to erect his ship railway, to take the largest vessels, fully laden and equipped, from sea to sea, over a gigantic railway across the Isthmus of Tehuantepec, a distance of 95 miles. Mr. Barnaby, the chief constructor of the navy, and Mr. John Fowler have expressed a favorable opinion regarding this enterprise, and it is to be hoped that both the canal and the ship railway will be accomplished, as it may be safely anticipated that the traffic will be amply sufficient to support both these undertakings.

Whether or not M. de Lesseps will be successful also in carrying into effect the third great enterprise with which his name has been prominently connected, the flooding of the Tunis-Algerian Chotts, thereby re-establishing the lake Tritonis of the ancients, with its verdure-clad shores, is a question which could only be decided upon the evidence of accurate surveys, but the beneficial influence of a large sheet of water within the African desert could hardly be matter of doubt.

It is with a feeling not unmixed with regret that I have to record the completion of a new Eddystone Lighthouse in substitution for the *chef-d'œuvre* of engineering erected by John Smeaton more than 100 years ago. The condemnation of that structure was not, however, the

consequence of any fault of construction, but was caused by inroads of the sea upon the rock supporting it. The new lighthouse, designed and executed by Mr., now Sir, James Douglass, engineer of Trinity House, has been erected in the incredibly short time of less than two years, and bids fair to be worthy of its famed predecessor. Its height above high water is 130 feet, as compared with 72 feet, the height of Telford's structure, which gives its powerful light a considerably increased range. The system originally suggested by Sir William Thomson some years ago, of distinguishing one light from another by flashes following at varied intervals, has been adopted by the Elder-Brethren in this as in other recent lights, in the modified form introduced by Dr. John Hopkinson, in which the principle is applied to revolving lights, so as to obtain a greater amount of light in the flash.

The geological difficulties which for some time threatened the accomplishment of the St. Gothard Tunnel have been happily overcome, and this second and most important sub-Alpine thoroughfare now connects the Italian railway system with that of Switzerland and the south of Germany, whereby Genoa will be constituted the shipping port for those parts.

Whether we shall be able to connect the English with the French railway system by means of a tunnel below the English channel is a question that appears dependent at this moment rather upon military and political than technical and financial considerations. The occurence of a stratum of impervious grey chalk, at a convenient depth below the bed of the channel, minimizes the engineering difficulties in the way, and must influence the financial question involved. The protest lately raised against its accomplishment can hardly be looked upon as a public verdict, but seems to be the result of a natural desire to pause pending the institution of careful inquiries. These inquiries have been made by a Royal Scientific Commission, and will be referred for further consideration to a mixed Parliamentary Committee, upon whose report it must depend whether the natural spirit of commercial enterprise has to yield in this instance to political and military considerations. Whether the channel tunnel is constructed or not the plan proposed some years ago by Mr. John Fowler of connecting England and France by means of a ferry boat capable of taking railway trains would be a desideratum justified by the ever-increasing inter-communication between this and Continental countries.

The public inconvenience arising through the obstruction to traffic by a sheet of water is well illustrated by the circumstance that both the estuaries of the Severn and of the Mersey are being undermined in order to connect the railway systems on the two sides, and that the Frith of Forth is about to be spanned by a bridge exceeding in grandeur anything as yet attempted by the engineer. The roadway of this bridge will stand 150 feet above high-water mark, and its two principal spans will measure a third of a statute mile each. Messrs. Fowler and Baker, the engineers to whom this great work has been entrusted, could hardly have accomplished their task without having recourse to steel for their material of construction, nor need the steel used be of the extra mild quality particularly applicable for naval structures to withstand collision, for, when such extreme toughness is not required, steel of very homogeneous quality can be produced, bearing a tensile strain double that of iron.

The tensile strength of steel, as is well known, is the result of an admixture of carbon with the iron, varying between $\frac{1}{10}$th and 2 per cent., and the nature of this combination of carbon with iron is a matter of great interest both from a theoretical and practical point of view. It could not be a chemical compound which would necessitate a definite proportion, nor could a mere dissolution of the one in the other exercise such remarkable influence upon the strength and hardness of the resulting metal. A recent investigation by Mr. Abel has thrown considerable light upon this question. A definite carbide of iron is formed, it appears soluble at high temperatures in iron, but separating upon cooling the steel gradually, and influencing only to a moderate degree the physical properties of a metal as a whole. In cooling rapidly there is no time for the carbide to separate from the iron, and the metal is thus rendered both hard and brittle. Cooling the metal gradually under the influence of great compressive force, appears to have a similar effect to rapid cooling in preventing the separation of the carbide from the metal, with this difference, that the effect is more equal throughout the mass, and that more uniform temper is likely to result.

When the British Association met at Southampton on a former occasion, Schönbein announced to the world his discovery of gun-cotton. This discovery has led the way to many valuable researches on explosives generally, in which Mr. Abel has taken a leading part. Recent investigations by him, in connection with Captain Noble, upon

the explosive action of gun-cotton and gunpowder confined in a strong chamber, which have not yet been published, deserve particular attention. They show that while by the method of investigation pursued about twenty years ago by Karolye (of exploding gunpowder in very small charges in shells confined within a large shell partially exhausted of air), the composition of the gaseous products was found to be complicated and liable to variation, the chemical metamorphosis which gun-cotton sustains, when exploded under conditions such as obtained in its practical application, is simple and very uniform. Among other interesting points noticed in this direction was the fact that, as in the case of gunpowder, the proportion of carbonic acid increases, while that of carbonic oxide diminishes with the density of the charge. The explosion of gun-cotton, whether in the form of wool or loosely spun thread, or in the packed compressed form devised by Abel, furnished practically the same results if fired under pressure, that is, under strong confinement—the conditions being favorable to the full development of its explosive force ; but some marked differences in the composition of the products of metamorphosis were observed when gun-cotton was fired by detonation. With regard to the tension exerted by the products of explosion, some interesting points were observed, which introduce very considerable difficulties into the investigation of the action of fired gun-cotton. Thus, whereas no marked differences are observed in the tension developed by small charges and by very much larger charges of gunpowder having the same density (*i. e.* occupying the same volume relatively to the entire space in which they are exploded), the reverse is the case with respect to gun-cotton. Under similar conditions in regard to density of charge, 100 grammes of gun-cotton gave a measured tension of about 20 tons on the square inch, 1,500 grammes gave a tension of about 29 tons (in several very concordant observations), while a charge of 2·5 kilos gave a pressure of about 45 tons, this being the maximum measured tension obtained with a charge of gunpowder of five times the density of the above.

The extreme violence of the explosion of gun-cotton as compared with gunpowder when fired in a closed space was a feature attended with formidable difficulties. In whatever way the charge was arranged in the firing cylinder, if it had free access to the enclosed crusher gauge, the pressures recorded by the latter were always much greater than when means were taken to prevent the wave of matter suddenly set in motion from acting directly upon the gauge. The

abnormal, or wave-pressures recorded at the same time that the general tension in the cylinder was measured, amounted in the experiment to 42·3 tons, when the general tension was recorded at 20 tons; and in another when the pressure was measured at 29 tons, the wave-pressure recorded was 44 tons. Measurements of the temperature of explosion of gun-cotton showed it to be about double that of the explosion of gun-powder. One of the effects observed to be produced by this sudden enormous development of heat was the covering of the inner surfaces of the steel explosion-vessel with a net-work of cracks, small portions of the surface being sometimes actually fractured. The explosion of charges of gun-cotton up to 2·5 kilos in perfectly closed chambers, with development of pressures approaching to 50 tons on the square inch, constitutes alone a perfectly novel feat in investigations of this class.

Messrs. Noble and Abel are also continuing their researches upon fired gunpowder, being at present occupied with an inquiry into the influence erected upon the chemical metamorphosis and ballistic effects of fired gunpowder by variation in its composition, their attention being directed especially to the discovery of the cause of the more or less considerale erosion of the interior surface of guns produced by the exploding charge—an effect which, notwithstanding the application of devices in the building up of the charge specially directed to the preservation of the gun's bore, has become so serious that, with the enormous charges now used in our heavy guns, the erosive action on the surface of the bore produced by a single round is distinctly perceptible. As there appeared to be *primâ facie* reasons why the erosive action of powder upon the surface of the bore at the high temperatures developed should be at any rate in part due to its one component sulphur, Noble and Abel have made comparative experiments with powders of usual composition and with others in which the proportion of sulphur was considerably increased, the extent of erosive action of the products escaping from the explosion vessel under high tension being carefully determined. With small charges a particular powder containing no sulphur was found to exert very little erosive action as compared with ordinary cannon powder; but another powder, containing the maximum proportion of sulphur tried (15 per cent.), was found equal to it under these conditions, and exerted very decidedly less erosive action than it, when larger charges were reached. Other important contributions to our knowledge of the action of fired gun-

powder in guns, as well as decided improvements in the gunpowder manufactured for the very heavy ordnance of the present day, may be expected to result from a continuance of these investigations. Professor Carl Himly, of Kiel, having been engaged upon investigations of a similar nature, has lately proposed a gunpowder in which hydrocarbons precipitated from solution in naphtha take the place of the charcoal and sulphur of ordinary powder, this powder has amongst others the peculiar property of completely resisting the action of water, so that the old caution, "Keep your powder dry," may hereafter be unnecessary.

The extraordinary difference of condition, before and after its ignition, of such matter as constitutes an explosive agent leads us up to a consideration of the aggregate state of matter under other circumstances. As early as 1776 Alexander Volta observed that the volume of glass was changed under the influence of electrification, by what he termed electrical pressure. Dr. Kerr, Govi, and others have followed up the same inquiry, which is at present continued chiefly by Dr. George Quincke, of Heidelberg, who finds that temperature, as well as chemical constitution of the dielectric under examination, exercises a determining influence upon the amount and character of the change of volume effected by electrification; that the change of volume may under certain circumstances be effected instantaneously as in flint glass, or only slowly as in crown glass, and that the elastic limit of both is diminished by electrification, whereas in the case of mica and gutta-percha an increase of elasticity takes place.

Still greater strides are being made at the present time towards a clearer perception of the condition of matter when particles are left some liberty to obey individually the forces brought to bear upon them. By the discharge of high tension electricity through tubes containing highly rarefied gases (Geissler's tubes), phenomena of discharge were produced which were at once most striking and suggestive. The Sprengel pump afforded a means of pushing the exhaustion to limits which had formerly been scarcely reached by the imagination. At each step the condition of attenuated matter revealed varying properties when acted upon by electrical discharge and magnetic force. The radiometer of Crookes imported a new feature into these inquiries, which at the present time occupy the attention of leading phycicists in all countries.

The means usually employed to produce electrical discharge in

vacuum tubes was Ruhmkorff's coil; but Mr. Gassiot first succeeded in obtaining the phenomena by means of a galvanic battery of 3,000 Leclanché cells. Dr. De La Rue, in conjunction with his friend Dr. Hugo Müller, has gone far beyond his predecessors in the production of batteries of high potential. At his lecture "On the Phenomena of Electric Discharge," delivered at the Royal Institution in January 1881, he employed a battery of his invention consisting of 14,400 cells (14,832 Volts), which gave a current of 0·054 Ampère, and produced a discharge at a distance of 0·71 inch between the terminals. During last year he increased the number of cells to 15,000 (15,450 Volts), and increased the current to 0·4 Ampère, or eight times that of the battery he used at the Royal Institution.

With the enormous potential and perfectly steady current at his disposal, M. De La Rue has been able to contribute many interesting facts to the science of electricity. He has shown, for example, that the beautiful phenomena of the stratified discharge in exhausted tubes are but a modification and a magnification of those of the electric arc at ordinary atmospheric pressure. Photography was used in his experiments to record the appearance of the discharge, so as to give a degree of precision otherwise unattainable in the comparison of the phenomena. He has shown that between two points the length of the spark, provided the insulation of the battery is efficacious, is as the square of the number of cells employed. Mr. De La Rue's experiments have proved that all pressures the discharge in gases is not a current in the ordinary acceptation of the term, but is of the nature of a disruptive discharge. Even in an apparently perfectly steady discharge in a vacuum tube, when the strata as seen in a rapidly revolving mirror are immovable, he has shown that the discharge is a pulsating one; but, of course, the period must be of a very high order.

At the Royal Institution, on the occasion of his lecture, Mr. De La Rue produced, in a very large vacuum tube, an imitation of the Aurora Borealis; and he has deduced from his experiments that the greatest brilliancy of Aurora displays must be at an altitude of from thirty-seven to thirty-eight miles—a conclusion of the highest interest, and in opposition to the extravagant estimate of 281 miles at which it had been previously put.

The President of the Royal Society has made the phenomena of electrical discharge his study for several years, and resorted in his important experiments to a special source of electric power. In a note

addressed to me, Dr. Spottiswoode describes the nature of his investigations much more clearly than I could venture to give them. He says: "It had long been my opinion that the dissymmetry shown in electrical discharges through rarefied gases must be an essential element of every disruptive discharge, and that the phenomena of stratification might be regarded as magnified images of features always present, but concealed under ordinary circumstances. It was with a view to the study of this question that the researches by Moulton and myself were undertaken. The method chiefly used consisted in introducing into the circuit, intermittence of a particular kind, whereby one luminous discharge was rendered sensitive to the approach of a conductor outside the tube. The application of this method enabled us to produce artificially a variety of phenomena, including that of stratification. We were thus led to a series of conclusions relating to the mechanism of the discharge, among which the following may be mentioned:

1. That a stria, with its attendant dark space, forms a physical unit of a striated discharge; that a striated column is an aggregate of such units formed by means of a step-by-step process; and that the negative glow is merely a localized stria, modified by local circumstances.

2. That the origin of the luminous column is to be sought for at its negative end; that the luminosity is an expression of a demand for negative electricity; and that the dark spaces are those regions where the negative terminal, whether metallic or gaseous, is capable of exerting sufficient influence to prevent such demand.

3. That the time occupied by electricity of either name in traversing a tube is greater than that occupied in traversing an equal length of wire, but less than that occupied by molecular streams (Crookes' radiations) in traversing the tubes. Also that, especially in high vacua, the discharge from the negative terminal exhibits a durational character not found at the positive.

4. That the brilliancy of the light with so little heat may be due in part to brevity in the duration of the discharge; and that for action so rapid as that of individual discharges, the mobility of the medium may count as nothing; and that for these infinitesimal periods of time gas may itself be as rigid and as brittle as glass.

5. That striæ are not merely loci in which electrical is converted into luminous energy, but are actual aggregations of matter.

This last conclusion was based mainly upon experiments made with

an induction coil excited in a new way, viz.: directly by an alternating machine, without the intervention of a commutator or condenser. This mode of excitement promises to be one of great importance in spectroscopic work, as well as in the study of the discharge in a magnetic field, partly on account of the simplification which it permits in the construction of induction coils, but mainly on account of the very great increase of strength in the secondary currents to which it gives rise."

These investigations assume additional importance when we view them in connection with solar—I may even say stellar—physics, for evidence is augmenting in favor of the view that interstellar space is not empty, but is filled with highly attenuated matter of a nature such as may be put into our vacuum tubes. Nor can the matter occupying stellar space be said any longer to be beyond our reach for chemical and physical test. The spectroscope has already thrown a flood of light upon the chemical constitution and physical condition of the sun, the stars, the comets, and the far distant nebulæ, which have yielded spectroscopic photographs under the skilful management of Dr. Huggins, and Dr. Draper of New York. Armed with greatly improved apparatus the physical astronomer has been able to reap a rich harvest of scientific information during the short periods of the last two solar eclipses; that of 1879, visible in America, and that of May last, observed in Egypt by Lockyer, Schuster, and by Continental observers of high standing. The result of this last eclipse expedition has been summed up as follows: "Different temperature levels have been discovered in the solar atmosphere; the constitution of the corona has now the possibility of being determined, and it is proved to shine with its own light. A suspicion has been aroused once more as to the existence of a lunar atmosphere, and the position of an important line has been discovered. Hydro-carbons do not exist close to the sun, but may in space between us and it."

To me, personally, these reported results possess peculiar interest, for in March last I ventured to bring before the Royal Society a speculation regarding the conservation of solar energy, which was based upon three following postulates, viz.:

1. That aqueous vapor and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the effect of solar rotation is to draw in dissociated vapors

upon the polar surfaces, and to eject them after combustion has taken place back into space equatorially.

It is, therefore, a matter of peculiar gratification to me that the results of observation here recorded give considerable support to that speculation. The luminous equatorial extensions of the sun which the American observations revealed in such a striking manner (with which I was not acquainted when writing my paper) were absent in Egypt; but the outflowing equatorial streams, I suppose to exist, could only be rendered visible by reflected sunlight, when mixed with dust produced by exceptional solar disturbances or by electric discharge; and the occasional appearance of such luminous extensions would serve only to disprove the hypothesis entertained by some, that they are divided planetary matter, in which case their appearance should be permanent. Professor Langley, of Pittsburgh, has shown by means of his Bolometer, that the solar actinic rays are absorbed chiefly in the solar instead of in the terrestrial atmosphere, and Captain Abney has found by his new photometric method that absorption due to hydro-carbons takes place somewhere between the solar and terrestrial atmosphere; in order to test this interesting result still further, he has lately taken his apparatus to the top of the Riffel with a view of diminishing the amount of terrestrial atmospheric air between it and the sun, and intends to bring a paper on this subject before Section A. Stellar space filled with such matter as hydro-carbon and aqueous vapor would establish a material continuity between the sun and his planets, and between the innumerable solar systems of which the universe is composed. If chemical action and reaction can further be admitted, we may be able to trace certain conditions of thermal dependence and maintenance, in which we may recognize principles of high perfection, applicable also to comparatively humble purposes of human life.

We shall thus find that in the great workshop of nature there are no lines of demarkation to be drawn between the most exalted speculation and commonplace practice, and that all knowledge must lead up to one great result, that of an intelligent recognition of the Creator through His works. So then, we members of the British Association and fellow-workers in every branch of science, may exhort one another in the words of the American bard who has so lately departed from amongst us:

> Let us then be up and doing,
> With a heart for any fate;
> Still achieving, still pursuing,
> Learn to labor and to wait.

RUFUS HILL'S SPARK ARRESTER.

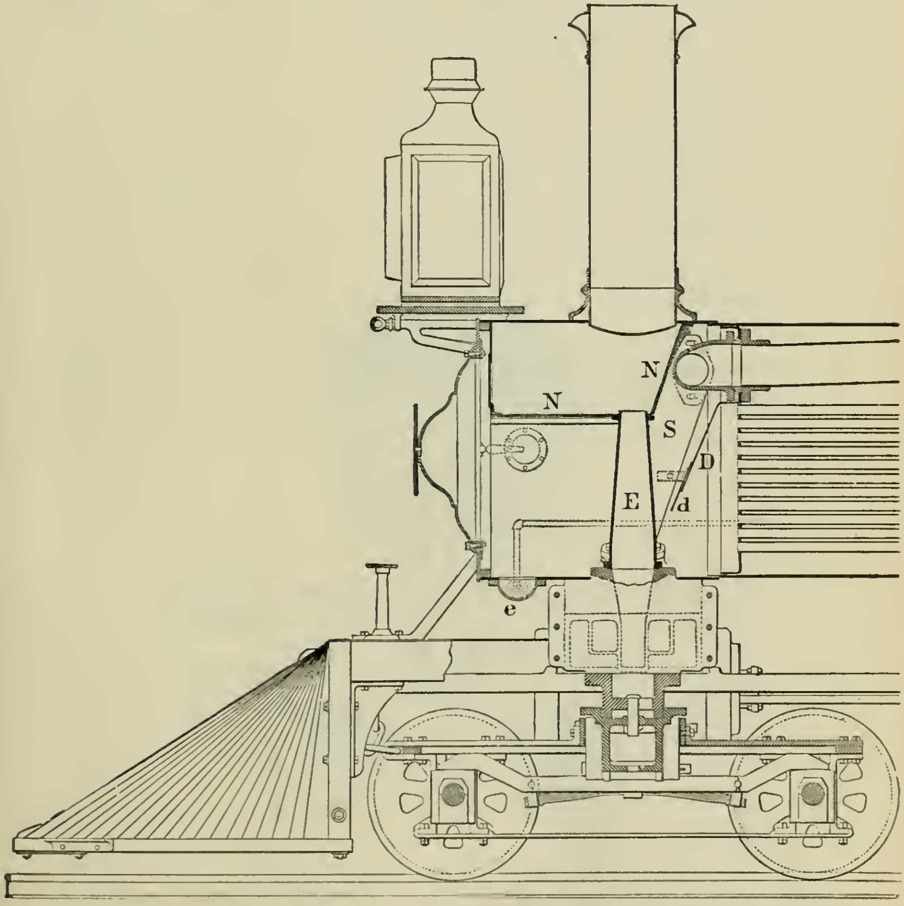
[From the report of the Secretary, November 15, 1882.]

The spark arrester, designed by Rufus Hill, M. M., Camden and Atlantic Railroad, is intended not only to prevent the escape of cinders and unconsumed fuel from the stack, but also, by regulating and equalizing the draught through the tubes, to effect a reduction in the amount of solid matter drawn from the fire-box by the action of the exhaust.

It is a recognized fact that in locomotive and other tubular boilers, the draught is materially stronger through the upper than through the lower tubes, this being due to the natural tendency of the escaping products of combustion to ascend, promoted by the higher temperature which prevails in the upper portion of the boiler. The upper tubes hence do more, and the lower less than their normal duty, and the portions of fuel which are lifted from the grate bars by the exhaust are drawn, relatively, rapidly through the upper tubes and slowly through the lower ones, tending, in the former case, to be thrown forcibly out of the stack, and in the latter, to clog the tubes. To counteract the effect of such unequal action, a deflecting plate is located by Mr. Hill in front of the flue head, and acts by checking the undue draught through the upper tubes, to proportionately induce an increased draught through the lower ones, also deflecting the escaping sparks and cinders from their natural upward course towards the bottom of the smoke box where the action of the exhaust is insufficient to overcome their gravity and carry them with the gases out of the stack. The lighter particles are arrested by a netting, the construction of which is such as to afford ample separating surface without undue increase of the volume of the smoke-box.

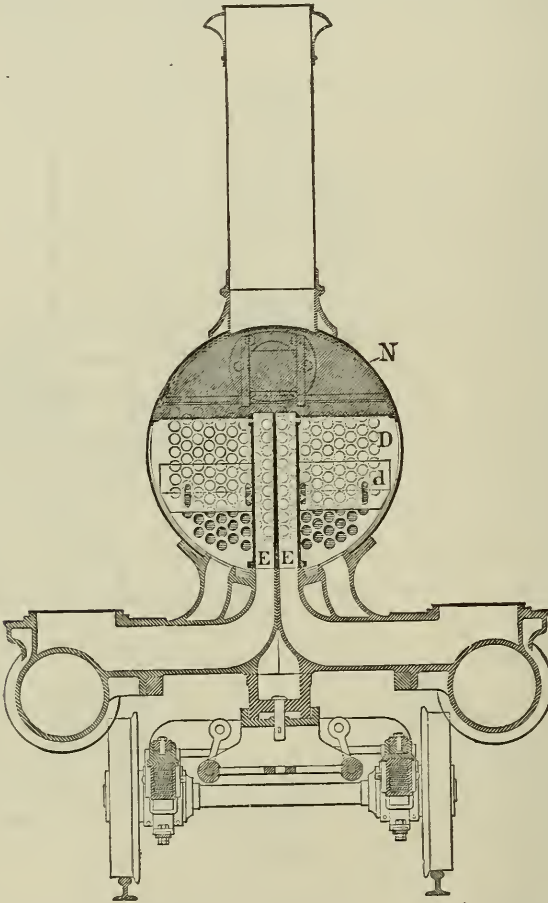
The illustrations, which are, respectively, longitudinal and transverse sections at the centre of the stack, show the improvements as applied to engines Nos. 17 and 18 of the Camden and Atlantic Railroad. These engines, which were built by the Baldwin Locomotive Works, are of the standard "American" pattern, with $16 \times 24''$ cylinders, $5' \ 6''$ drivers, and fire-boxes 9 ft. $1\frac{1}{2}'' \times 42''$ inside dimensions. (Grate surface $31\frac{9}{10}$ sq. ft.) They are adapted to burn either anthracite or bituminous coal, but have been used principally with the latter, and in service, on fast express and heavy excursion trains, their performance has been satisfactory in all particulars.

The deflecting plate D, is secured to the front flue-sheet, just above the upper row of tubes, and after projecting horizontally for such distance as to afford a space between the flue sheet and its adjacent side sufficient for the free discharge of the products of combustion from the top row of tubes, is thence inclined downwardly and outwardly from the flue sheet to its lower edge, thus affording a uniformly increasing



area of horizontal section in the discharge space formed between it and the flue sheet, in correspondence with the increasing areas of tube section presented by the several lower rows of tubes in front of which it is located. The deflector is connected at its sides to the boiler shell and smoke-box, so as to make tight joints therewith, and to admit of

such variation in the opening beneath it as may be required by differences in the duty or steaming qualities of engines, or in the character of fuel employed, an adjustable section, d, is attached to its lower side by bolts passing through slotted holes so as to be raised or lowered as desired. The use of the deflecting plate enables the usual "petticoat"



or lift pipe to be dispensed with, and a long exhaust pipe E, is employed, giving a "straight shot" exhaust into an open 16″ stack.

The netting N, which is of $\frac{1}{4}''$ mesh wire, extends horizontally across the smoke-box, from a plate at its front to the rear of the exhaust pipe, and thence is inclined upwardly, between the steam pipes S, and the lower opening of the stack, being secured to the smoke-box

by angle iron extending along its horizontal and inclined portions. A hand-hole and bonnet on the side of the smoke-box, shown in dotted lines, affords access to the lower side of the netting, and there is also an opening in the front plate above the netting, closed by a sliding cover. Cinders and unburned fuel which collect in the smoke box are blown out by a jet of steam through the ejector c, or they may be dropped into a "sub-treasury" below the smoke-box. With fire-boxes of proper proportions, as in the engines referred to, an extension of the smoke-box beyond that which will admit of the attachment of an ejector or discharge pipe, is not found to be either necessary or advisable, but the deflecting plate and netting are equally applicable where an extended smoke box is considered to be a proper spark receptacle.

The Hill spark arrester is now in use, and it is said, with satisfactory results, on a large number of engines, about 213 having been fitted with it by the Baldwin Locomotive Works, among which are 42 on the Manhattan (Elevated) Railroad, New York, the entire equipment of the Shenandoah Valley Railroad, 25 in number, together with engines of the Pennsylvania, Richmond, Fredericksburg and Potomac, Central Pacific, Western Maryland, and other railroads, and the single-driver engine sent to England by the Eames Vacuum Brake Co.

ON A NEW SWEET COMPOUND.

By Constantine Fahlberg, Ph.D.

[Abstract of a paper read at the Stated Meeting of the Franklin Institute, Jan. 17, 1883.]

Gentlemen:—Some time ago ("American Chemical Journal," Vol. I, page 430), in connection with an investigation upon the hydrocarbons of the coal tar group, it was discovered that a certain compound obtained by the oxydation of toluene-sulphamide with potassium permanganate tasted sweet. The sweetness was so intense that a few drops of the cold mother-liquor, remaining on and being partly washed off my hands, could be easily detected by the taste.

As soon as I had discovered this property, peculiar only to this particular mother-liquor, the substance obtained from it was subjected to several tests in order to determine whether it was poisonous to take it in larger quantities or not. At first a cat and then a dog were subjected to this cruel experiment, but they remaining fortunately alive and apparently not in the slightest degree affected by it, I decided to take

several grammes of it myself. The result was not the slightest inconvenience experienced from it. I subjected, the next morning, my urine to the chemical test, and found it to contain almost the entire quantity taken the previous night.

The compound which I now will exhibit to you forms salts with any carbonate of the alkalies, alkaline earths or metals and all of which you will find taste sweet. It is, however, not an acid, but belongs to a class of bodies which Professor Remsen and myself have given the name of "Sulphinides," the compound in question being benzoic sulphinide. It is very readily soluble in alcohol, more so than in cold water, in which it only dissolves readily when it is hot.

I am making the attempt now to prepare it in larger quantities and by cheaper methods, and have no doubt that it will find extensive use in medicine and for technical purposes.

One experiment made lately was to sweeten glucose, which as you all know tastes only faintly sweet, and the result was a complete success.

As soon as I shall have found the method by which to prepare it on a manufacturing scale I shall come before you again, and as I trust and hope, with larger samples than now, ready to give answer to all questions in regard to its price, application, etc.

Study of Atmospheric Electricity.—Among the useful applications of Mascart's electrometer, is the photographic registry of the variations in atmospheric electricity. It is necessary to maintain a perfect insulation of the different portions of the apparatus, otherwise, instead of getting a curve which represents the variations of atmospheric potential, the curve will be some unknown function of those variations and of the greater or less conductibility of the supports. Dampness, dust, spider-webs, etc., are the principal disturbances of insulation. The automatic record is made by sending a beam of light in a constant direction upon the mirror of the electrometer, which reflects it to a sensitive photographic plate moving uniformly in a direction perpendicular to the plane in which the reflected ray is displaced by the oscillations of the mirror. Since continuous observations are the only ones which take into account the varied and frequent modifications of atmospheric electricity, this method is very valuable and will doubtless lead to interesting results.—*L'Electricien*, October 15, 1882. C.

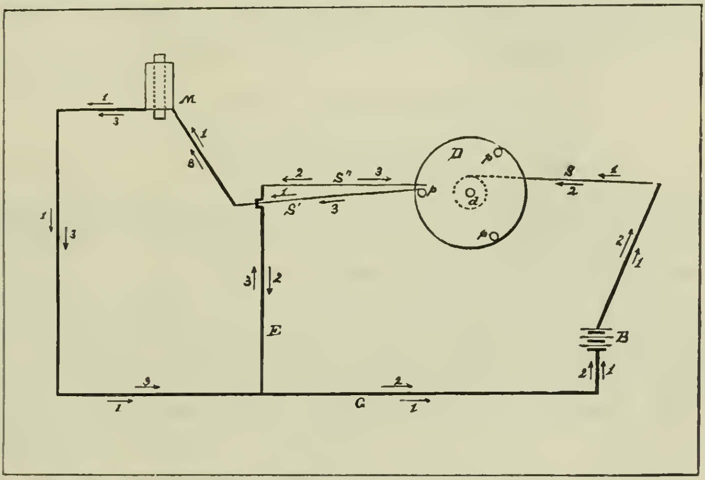
A SPARKLESS CURRENT-BREAKER.

By Louis H. Spellier.

The fact that the spark of the induced current of electro-magnetic instruments will destroy the contact surfaces by which the making and breaking of the circuit is effected, is very keenly felt on current-breakers for electro-magnetic time telegraphs.

A device for the purpose of obviating the spark, invented by Dr. Hipp, has been in use successfully for some years at Geneva, to distribute astronomical time through the different sections of that city.

The writer presents in the accompanying diagram a device of his



own for the same purpose, which, he believes, will commend itself for simplicity as well as for effectiveness.

With the exception of an additional contact spring, S″, the current-breaker is the same as described in the Journal of the Franklin Institute, August number, 1882.

The metal disk D, is fastened to the axle of the escape-wheel of a clock, and has as many platinum pins *p*, attached vertically upon its face, as there are openings and closings of the circuit needed during the time it completes one revolution. *d* is a platinum disk; fastened to the pin-bearing disk; S and S′ are two contact springs. The spring S, rests upon the platinum disk, while S′ is to make the contact with the pins *p*. When the disk moves with the escape-wheel of the clock, and

the spring S′ comes in contact with one of the pins p, the circuit of the battery is completed, and broken when removed from it.

In the diagram, D represents the current-breaker; B the battery; M, the electro-magnet; and G, the ground conductor. The spring S′ is in contact with a pin and thereby completes the circuit. The current now takes the course as shown by the arrows 1. The contact spring S″ is placed a little higher than S′, and therefore does not yet touch the pin p. But as soon as D moves on again, S″ will a moment before S′ leaves the pin come also in contact with it; at this moment S″ will make a short circuit through the conductor E, and the course of the battery current becomes that of the arrows 2, while the induced current of M, at the moment the short circuit is made, takes the course as indicated by the arrows 3. A moment after S′ leaves p, S″ follows it, and the short circuit of the battery is also broken.

Book Notices.

Physics and Occult Qualities. An Address delivered before the Philosophical Society of Washington, December 2, 1882, by William B. Taylor, retiring President of the Society.

In these days of scientific dogmatism, it is refreshing to find a good thinker and acute reasoner, who is bold enough to admit that there are such things as "occult qualities;" that "force" is a reality, the function of which "is attended with no expenditure, and is capable of no exhaustion;" that the highest induction "accounts consistently for the unfaltering obedience and instantaneous response of all the countless atoms of the universe to the reign of 'law,' by positing behind such law, an Infinite Law-giver."

These acknowledgments are made with a degree of candor, which is as commendable as it is remarkable. It would be difficult to find, elsewhere, so concise and so fair a statement, both of the triumphs and of the insuperable obstacles of the kinematic theory, or so ready an admission that even the dynamic theory does no more than acquiesce in its results, and accepts the established properties of matter "as ultimate and inexplicable."

The conclusion (p. 36) "that matter is capable of acting *only* where it is not," diametrically opposed as it is to the old and common notion "that nothing can act save where it is," will undoubtedly strike many

readers as "absurd, incomprehensible, inconceivable" and paradoxical. It is, however, well sustained, by reasoning which may be commended to the careful study of all who are inclined to discard metaphysics and to believe that all phenomena can be explained by methods which are altogether mechanical. Mr. Walter R. Browne (*Phil. Mag.* Dec. 1880; Jan. 1883) has also adduced cogent arguments to show the necessity of granting action at a distance.

The experiments of Guthrie (1870) and Bjerknes (1881) upon attractions and repulsions by the influence of vibrations are cited, but no reference is made to Chase's earlier experiments with magnetic needles, which were published in 1864 (*Proc. Am. Phil. Soc.*, ix, 359; x, 151–66).

We note but one seeming inconsistency in the whole address (p. 48): "*Under the present system of dynamic law,* it is certain that as radiating and cooling bodies,

> 'The stars shall fade away, the sun himself
> Grow dim with age, and nature sink in years.'

Nor is there known to science any natural process whereby this cosmic doom may be either averted or repaired by exterior reversal." This is a kinematic, rather than a dynamic conclusion, and it is dynamically controverted by the fact that the velocity of light, the velocity of electro-dynamic action, and the velocity of the gravitating time-integral of solar rotation, are each equivalent to the thermal unit of velocity at the centre of our system which is indicated by Laplace's principle of periodicity (*Photodynamic Notes*, 280, 321, 333; *Proc. Am. Phil. Soc.*, vol. xx). C.

MANUAL OF BLOW-PIPE ANALYSIS AND DETERMINATIVE MINERALOGY. By H. B. Cornwall. D. Van Nostrand, 1882.

The multiplication of manuals and text-books is so great in certain branches of science that the author frequently begins his preface by apologizing for ever having written the work at all. This is the case, *e. g.*, in treatises upon qualitative chemical analysis, in manuals on geology, in ordinary school books, arithmetics, etc. But it can hardly be said to be the case in regard to works like the one we are now considering. The use of the blow-pipe in chemistry and mineralogy cannot be too greatly appreciated. The behavior of minerals, ores, and inorganic bodies in general at a high temperature, their fusibility, their reactions with fluxes, their properties in an oxidizing atmosphere, in a

reducing atmosphere, the alloys they form, their affinities for oxygen, for sulphur, their coloring power, all of these and many other properties can be determined by this little instrument with ease and certainty, and it may be stated as a fact, that whoever has thoroughly mastered the study of blow-pipe analysis must necessarily be well grounded in the principles that underlie the more important science of metallurgy, since the elements exhibit the same reactions in the small tests that they do in the large smelting works.

Mr. Cornwall's book is an octavo of some three hundred pages, containing, in practical effect, all of value to be found in Plattner's large treatise, both in qualitative and *quantitative* work. Nor is any one better fitted to abridge this standard authority than our author, since the English translations of Plattner have come from his pen.

The qualitative reactions and separations are given with great fullness and very clearly, a number of new ones being introduced. Bunsen's Flame Reactions are omitted, and without any great loss to the work, as we cannot remember ever having heard of their being used by any one other than Bunsen himself.

The system of determinative mineralogy—an important part of the work—is to a great extent new, and is excellent. We notice one or two trifling errors: the formula of Sepiolite is not correct, and the per cent. of water in Hollaysite, as given, does not correspond with its formula.* In the chapter on quantitative analysis Plattner's Chromium Assay is wisely omitted, as it is a worthless process. The Iron Assay might also have been left out with advantage since the method described is obsolete and incorrect.

We can recommend this work as being a valuable one, either to the student or to the trained mineralogist or chemist. H. P., Jr.

Vanadium Green.—The treatment of the slags which are produced in the dephosphoration of certain smeltings at Creuzot, has furnished Messrs. Osmont and Witz considerable quantities of vanadic acid. This acid is produced by the reaction of oxygen upon vanadium; on treating it with chlorhydric acid a beautiful green color is obtained, which may be employed in dyeing.—*Les Mondes*, iii, 253. C.

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* Since writing the above we have noticed several other minerals whose formulæ are incorrectly given. This is apt to lead the student astray, and is worthy of the author's attention in future editions.

ROBERT BRIGGS.

Robert Briggs was born on the 18th of June, 1822, in the city of Boston, Mass., and was educated in the public schools of that city. He early showed a special aptitude for mathematics, the use of which was to become so important in his career, and the proficiency thus acquired was maintained and increased during the whole of his subsequent life.

His technical education commenced in 1839, when, at the age of seventeen, he entered the office of Captain Alexander Parris, a civil engineer and architect of Boston and Charlestown, Mass. Here he remained for several years, partly in the capacity of pupil and partly in that of assistant, thus acquiring his first familiarity with the actual duties of the engineer. The practical education thus commenced continued uninterruptedly throughout all the following years of his life, and ranged over a broader field than it usually falls to the lot of any individual to cover with his personal experience. It included nearly all of the more important branches of work which are usually comprehended in the duties of both the civil and mechanical engineer, from the work of the surveyor in the field and in the office, to the construction of the Washington Aqueduct; from the building of a rolling mill to the superintendence of the largest tube works in the country; from the heating and ventilating of a country school-house to that of the Capitol of the United States; from the designing of steam and gas fittings to that of the heaviest pumping engines; from the draughtman's board to the editor's table. In the performance of some of these duties he occupied subordinate positions under the direction of other engineers, but in most of them he was alone, and the work done by him, whether as designer, constructor, or manager, was in the fullest sense his own. Although not an inventor in the ordinary acceptation of the term, Mr. Briggs did more new and original work than most professional inventors. In some few cases he sought protection for these fruits of his brain by patents, but most of his conceptions and inventions were given freely to the engineering public without demand for compensation and without restriction of any kind. Mr. Briggs was a disbeliever in the expediency of the patent system, or at least believed that in most fields of industrial work its provisions are unnecessary, if not actually harm-

ful. He proved his faith in this belief by giving freely the products of his own inventive powers to those who sought them, leaving the question of compensation to be afterwards adjusted or, too frequently, to be entirely neglected. This bias (or peculiarity as it certainly was) is properly attributable to his deep interest in his own work and to the spirit of professional generosity which accompanied it and which prompted him. To him it was a pleasure of the highest kind to lay before others the results of his own study and work, and this pleasure he could not forego for the mere sake of hoarding his knowledge with the prospect of possibly turning it into ultimate pecuniary benefit.

Leaving Boston in 1844, Mr. Briggs went to the West, where for a short time he taught school. Returning from the West in 1845, he found temporary occupation as a clerk in Troy, N. Y., but the bent of his mind lay too strongly in the direction of engineering for him to be long diverted from his true channel of work. According, in 1847, we find that he returned to Boston, and after a few months work under Mr. Charles Hastings, C. E., in laying out a line of railway in Massachusetts, he accepted a position as "Constructing Engineer" to the Glendon Rolling Mill, a large and important establishment then being built at East Boston. Upon the completion of that work he opened an office of his own in Boston, as Architect and Engineer, an experiment which he repeated in Philadelphia in the later years of his life. This early experiment, like the later one, met with but small success, the practice of this country in engineering matters being too strongly established upon the basis of each establishment having its own engineer, to leave room for the profitable practice of a consulting engineer, although in England this latter calling is one of the most important and lucrative in the profession.

Mr. Briggs' connection with what was to become the most important professional association of his life, commenced in August, 1848, when he entered the service of Walworth & Nason, of Boston, and assumed the charge of the building of their Tube Works and the superintendence of the same when completed. One of the surviving partners of that firm, in writing recently of Mr. Briggs, states that during this connection "he proved himself to be an able and faithful engineer, fulfilling all the duties that devolved upon him with remarkable fidelity and ingenuity. His memory is cherished with great respect and affection."

In the latter part of 1852, Mr. Briggs accepted the position of

Superintending Engineer of the firm of Bird & Weld (now the Phœnix Works), of Trenton, N. J., where he was employed in the building of machinery for the manufacture of rubber and other miscellaneous purposes. Leaving here in November, 1853, he moved to Mount Savage, Md., where for six months he acted as Superintendent of the rolling mill at that place. Six months later, in May, 1854, he exchanged this position for that of Superintendent of the well-known Rensselaer Rolling Mill, at Troy, N. Y., in which position he remained for a year.

In 1855, Mr. Briggs accepted an appointment as Assistant Engineer under Captain (now General) M. C. Meigs, in which capacity he was employed at first in the direction of the building of the Washington Aqueduct, and, subsequently, in the erection of the iron work forming the dome of the Capitol at Washington, and in the heating and ventilating of the halls of Congress. During his connection with these important works, Mr. Briggs conducted an original investigation upon the strength and proportions of cast iron pipes, and published a diagramatic table of the same. This paper, we believe, to have been the first important one of the long series which flowed from his facile pen. While engaged upon the erection of the Capitol building, he designed a lathe for turning the large monolithic marble columns which form the portico of the Capitol, and in connection with the heating and ventilating of this building, made the elaborate and original researches which were subsequently embodied in his paper read before the British Institution of Civil Engineers, in 1870.

Leaving Washington in 1857, he early in the following year became a partner in the firm of Nason, Dodge & Briggs, of New York. The senior partner of this firm, Mr. Joseph Nason, was the pioneer, in this country at least, in the art of heating buildings by steam, and in this new association, Mr. Briggs continued and enlarged the experience he had already commenced while in the employ of Walworth & Nason, as a designer and constructor of appliances for heating by steam, including the manufacture of all kinds of brass and iron fittings for the same.

It is possible that the seductions of his mathematical acquirements and his already considerable appreciation of the theoretical conditions involved in the flow of air, and other questions involved in the heating and ventilating of buildings, may have interfered with commercial success in his new undertaking, or have disturbed the relations between himself and his more practical associates, for the partnership did not continue much more than one year.

Coming to Philadelphia in 1860, Mr. Briggs entered upon the longest and, in many respects, the most important engagement of his professional life, by accepting the position of Superintendent and Engineer of the Pascal Iron Works, of Morris, Tasker & Company. These works, under his management, became the largest and most important producers in this country of wrought pipes and boiler flues, of iron and brass fittings and valves, of machinery for cutting and screwing pipes, of appliances for steam and hot water heating, and of apparatus for gas works. The works when he assumed control of them, were in a comparatively disorderly condition, and his first efforts were directed to the bringing of "order out of chaos," in which he succeeded admirably, so that the works became a model of good management and economical operation. This done, he addressed himself to classifying and systematizing the varied products of the concern, and to the preparation of an illustrated catalogue of the same. This latter, a large quarto volume filled with illustrations of the many hundreds of articles produced under his management (many of the illustrations being reproduced from his own sketches), became the standard throughout the United States for the work of the several classes to which it relates, and is to-day a monument to his untiring industry and to his comprehensive grasp of a business of almost endless detail. In 1862-63 he designed and erected large additional buildings for the Pascal Works, including a new pipe mill and machine shop, which, when put in operation, proved convenient and economical and far better than any similar plant previously erected. At about this time Mr. Briggs also designated and constructed for the city of Galveston, Texas, a flat-top gas-holder, built without interior trussing. It is believed that this method, which was a radical and bold departure from existing precedents, although it is now almost universal, was original with Mr. Briggs. Among the improvements introduced by him in the manufacture of tools for pipe fittings, was the application of the Blanchard (or eccentric) lathe to tap making, by which the "backing off" of taps was done by machinery instead of by the laborious hand process previously in use.

In January, 1866, Mr. Briggs visited England on behalf of the Pascal Iron Works, chiefly to examine the Siemens' regenerative furnace, with a view to apply it to the heating of plates in tube making. He remained abroad four months, during which time he visited most of the engineering works in England, Scotland, and Belgium. His

reception by English engineers was remarkably cordial and appreciative. His intimate familiarity with American engineering practice, in many lines of work, and his readiness to impart freely all that he knew, as well as his clear appreciation of the points in American practice which would most interest English engineers, soon brought him into pleasant and intimate relations with many of the latter and led to friendships which continued up to the date of his death. On the other hand, his life-long habits of observation and his broad acquaintance with the industrial arts gave him an interest in everything that he saw, and his retentive memory was rapidly stored with facts relating to English practice in many fields of work. The knowledge thus acquired added largely to his professional resources, and was turned to account in many useful ways after his return.

His connection with the Pascal Iron Works was the longest of his professional career, lasting nine years, or until November, 1869. At its conclusion he again visited England, remaining there nearly a year, enlarging his acquaintance with English engineers, and continuing his study of their practice, particularly in connection with tube making. It was during this visit that he presented to the Society of Civil Engineers, his paper "On the Conditions and the Limits which govern the Proportions of Rotary Fans.* This essay was a philosophical inquiry into the action of these machines, and was of great interest and value, not only in regard to the ventilating fan, but also of its analogue, the turbine. The paper was awarded a Watt medal and a Telford premium. On the 4th of February, 1879, Mr. Briggs was elected a member of the British Institution of Civil Engineers, and about this time also became a member of the Institution of Mechanical Engineers.

Returning to the United States, Mr. Briggs, in January, 1871, became the superintendent and engineer of the Southwark foundry, then belonging to Mr. Henry G. Morris. These works, previously owned by Merrick & Towne, and later by Merrick & Sons, were engaged in heavy engineering work of wide variety, and the opportunity thus opened to Mr. Briggs was, in some respects, the pleasantest and most congenial in his career. During this connection he designed and built a pumping engine, for the city of Lowell, Mass., which may be regarded as the largest single work of his life. This machine was a compound rotative engine of the "Simpson" type, with a capacity of

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*Minutes of Proceedings, Inst. C. E., Vol, xxx., p. 236.

five million gallons per twenty-four hours under a head of one hundred and sixty feet. When completed it gave a "duty" of over one hundred millions, which, to those conversant with pumping machinery, is the best indication of its high qualities. In these works Mr. Briggs also designed and constructed a large variety of heavy work, including sugar mills and sugar refining machinery, gas apparatus, blast furnace engines and furnaces, stationary engines, nitrate of soda apparatus, etc. He also designed and built a large new foundry, and a thirty ton traveling crane operated by power. His engagement lasted until the closure of the works, which occurred in 1875, owing to causes resulting from the disturbance of the iron market, and wholly independent of his part in the management of the business.

For some time after the closing of the Southwark foundry Mr. Briggs was confined by illness. Recovering from this he again made a short visit to England. In 1876 he became the editor of the JOURNAL OF THE FRANKLIN INSTITUTE, which position he filled for several years, and for which his wide experience as an engineer, and his almost equal experience in the writing of papers, descriptive of engineering practice, eminently fitted him. A reference to the pages of the JOURNAL during his editorship will show how industriously he discharged his duties, and how well adapted he was to the performance of such work. His contributions were very numerous, and covered a great variety of subjects. In 1878 Mr. Briggs opened an office in Philadelphia as consulting engineer, devoting himself particularly to the designing of heavy machinery and iron work, to the application of heat in the arts, and to the designing of works for gas and water supply. His success in this experiment was only moderate for the reason, as above explained, that practice of this kind is not in vogue in this country, and obtains but little recognition and support.

In 1880 he became consulting assistant to Colonel Ludlow, United States Engineer of River and Harbor Improvements in the vicinity of Philadelphia. The terms of his engagement permitted him to retain a portion of his office practice, and he continued, until his final illness, to give more or less attention to miscellaneous engineering affairs, including particularly the heating and ventilating of large buildings. He continued also after the termination of his official connection with the JOURNAL OF THE FRANKLIN INSTITUTE to enrich its columns with contributions from his pen, and in addition to this did much other literary work. One of his papers, read before the Society of Civil Engi-

neers, of which Society he was a member, on the "Ventilation of Halls of Audience" attracted much attention. In it he urged that American engineers should discard European practice in this branch as unsuited to the conditions both of climate and physical constitution of the population; and he referred to the well authenticated fact that the modern American requires a temperature of not less than 70° F. for comfort, although his English cousins are comfortable in a room of 10° lower temperature. In 1881 Mr. Briggs presented to the British Institution of Civil Engineers an elaborate paper on "American Steam Heating Practice." Referring to this, the editor of one of our leading engineering journals writes as follows: "Although presenting few novelties to American readers it is probably the best exposition of the American system which has ever been presented to foreign engineers. In its historical details it is particularly full and valuable, Mr. Briggs having been early connected with the steam heating industry, and practically one of the first who applied scientific methods to it. To him the world is indebted for the system of pipe threads now employed, and the fittings which have practically become standard."

The foregoing outline, sketches briefly the salient points of Mr. Briggs' career as an engineer. It may be supplemented by the following tribute from a letter published soon after his death by one of his intimate friends. "One of his most notable traits was the comprehensive scope of his knowledge, which covered almost the entire field of engineering, both civil and mechanical, and included much also of metallurgy, chemistry, architecture, and applied sciences. On almost any topic under these heads he could discourse as a master, with a minuteness and familiarity astonishing to any but those who knew what an extraordinary range was covered by his personal experience in connection with mechanical and industrial operations, and who knew also how far these were supplemented by professional study and reading, continued uninterruptedly during the forty years of his business life. Added to these were the advantages of a good early education, an exceptional aptitude for mathematics (in which he excelled), and a very retentive memory. His temperament was placid and equable, and his companionship, a pleasure which his intimate friends at least can never forget."

Mr. Briggs had never enjoyed robust health, and, during portions of his life, his condition was almost that of an invalid. His vital strength had gradually failed during the latter years of his life, and in

December, 1881, after his return from a brief last visit to England, indications of paralysis developed. He continued work for some months longer, but ceased finally in April, 1882, at which time, on the advice of his physician, he left Philadelphia and went to his mother's home, in Dedham, Mass., where, on the 24th of July, 1882, he died of paralysis, resulting from tumor on the brain, after a lingering and painful illness, having just completed his sixtieth year.

Mr. Briggs' contributions to the literature of engineering were very numerous and valuable. Among them may be mentioned, in addition to the papers above referred to, his article "On the Transmission of Force by Belts and Pulleys," based on the experiments of Mr. Henry R. Towne, usually known as "Briggs' and Towne's experiments," which have been adopted in the text books both of this country and of England; a report on the "Ventilation of the House of Representatives, Washington;" a paper on the "Circulation of Water in Steam Boilers," etc.

It is to be hoped that the most valuable of Mr. Briggs' numerous papers may in time be republished in collected form, and thus made permanently available to the profession, to the advancement of which he contributed so largely during the many years of his active life.

HENRY G. MORRIS,
HENRY R. TOWNE,
B. C. TILGHMAN.

Heat and Magnetism.—L. Pilleux has lately called attention to the heating of iron during its magnetization. The fact had been previously observed by D. Tommasi in some researches which are not yet published upon the comparative study of the chemical properties of ordinary iron and of magnetized iron. In order to obtain a constant magnetic intensity he employed an electromangnet of a single branch in place of an ordinary magnet. When the current, eveh if it was produced by a weak battery, had traversed the coil for some hours, the magnetized bar became perceptibly warm. He at first attibuted the heating of the iron to the heating of the coil; but he was greatly astonished, one day when he had removed the bar in order to clean it and had forgotten to interrupt the current, to find that the coil was not heated at all.—*Les Mondes*, xxxi, 621. C.

Bleaching by Electricity.—Dobbie and Hutcheson have experimented upon bleaching by the aid of electrolysis. For this purpose the stuff is dipped into sea water and then passed through hot rolls which are connected with the poles of a galvanic battery. In order to decompose the hypochloride which is thus formed, the cloth is drawn through diluted acid and fully bleached.—*Dingler's Journal*, Oct., '82.

Gravity Barometer.—Mascart has invented a barometer in which the variations of weight are shown and measured by the changes of height in a column of mercury, which is in equilibrium with the pressure of a mass of gas. The instrument has been tested under shocks of every kind to which it would be exposed in traveling in Paris, Hamburg, Stockholm, Drontheim, and Tromsö. It was found to be readily transportable, and its precision did not appear to be inferior to that of the pendulum. It requires no other observation than that of the temperature and the level of the mercury, and the preparation can be made in less than an hour in a hotel chamber.—*Comptes Rendus*, Oct. 9, 1882, C.

Molecular Structure of Metals.—It is generally thought that the crystalline structure does not exist in metals which have been drawn or rolled. M. Kalischer has undertaken a series of experiments with cadmium, tin, copper, iron, steel, etc. He has arrived at the conclusion that the crystalline state corresponds to the natural molecular structure of metals. This state may be modified more or less easily by mechanical labor, but it is commonly reëstablished under the influence of heat. In some metals which have been drawn into wire the heat, while reëstablishing the crystalline structure, increases at the same time the electric conductibility.—*Chron. Industr.*, Oct. 19, 1882.

Light of Comets.—According to Huggins, comets emit a characteristic light which indicates, by spectral analysis, the presence of carbon, hydrogen, and nitrogen, elements which are shown by the spectra of acetylene and cyanhydric acid. Berthelot thinks that these results point to an electric origin of the light. He has shown that acetylene is formed immediately and necessarily whenever carbon and hydrogen come under the influence of the electric arc. When nitrogen is added to acetylene the electric influence produces cyanhydric acid. It seems scarcely possible to conceive of a continuous combustion in cometary matter, but an electric illumination may be easily understood.—*Ann. de Chim. et de Phys.*, Oct., 1882. C.

Use of Ethylene in Refrigerating.—Cailletet's experiments show that Ethylene is liquefied under the following pressures and temperatures:

60 atmospheres, . . .	10°C.	50°F.
56 " . .	8°C.	46·4°F.
50 " . . .	4°C.	39·2°F.
45 " . .	1°C.	33·8°F.

Its critical point is about 13° (55·4°F.), while that of carbonic acid is about 31° (87·8°F). These properties induced him to see whether liquefied ethylene would not give a more intense cold than that which corresponds to the ebullition of protoxide of nitrogen. By slightly modifying the apparatus which he used for liquefying oxygen, he succeeded in producing a more intense cold than had been previously realized. Ethylene, moreover, possesses the property of remaining liquid and transparent, under temperatures at which nitrogen protoxide and carbonic acid become solid and opaque. He hopes to obtain still greater degrees of cold by condensing gases which are more difficult to liquefy than ethylene.—*Comptes Rendus*, xciv, 1224. C.

Franklin Institute.

HALL OF THE INSTITUTE, February 21, 1883.

The meeting was called to order at the usual hour, with the President, Wm. P. Tatham, in the chair.

There were present 124 members and 39 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the last meeting, held Wednesday, February 14th, 7 persons had been elected to membership.

The Special Committee on "Prevention of Fires in Theatres," reported progress and was continued.

The Special Committee charged with the preparation of a memorial of the late Robert Briggs, presented a report which was read.

On motion of Mr. Hector Orr, seconded by Mr. J. B. Burleigh, the same was accepted and the Committee discharged, with the thanks of the Institute. The memorial appears in the current issue of the *Journal*.

The Secretary's report included a resume of matters of scientific interest, and an account of the following inventions:

The Pinkham Electric Gas Lighting Co.'s system of "Lighting and Extinguishing Gas by Electricity."

This is an attachment which may be adjusted to all styles of gas fixtures. It is of two forms, termed respectively the pendant and the automatic. The Leclanché battery is used to supply the electric current, and the connecting wire leading from the battery to the burners is concealed from view beneath the shell and ornamental portion of the fixture. The pendant form is provided with a light metal chain, terminated by a ball, a single pull of which turns on and lights the gas, while a second pull turns it off and extinguishes it. By the automatic form of the device, the gas is turned on and lighted or extinguised from one or several convenient points, by pressing an ivory button. By this means the gas in the hall of a house, for example, may be instantly lighted or extinguished from buttons located near the front door, at the head of the stairs, or wherever desired.

Specimens were shown of "Terra Cotta Lumber," made by the Terra Cotta Lumber Co., of New York. This material is used for fire proof construction of every description in architectural work, and is said also to be well adapted for filters, underground electrical insulation, steam boiler and pipe sheathing, fire lighters, imperishable ground sills, waterproof brick, grain and elevator bins, refrigerators, safe and vault linings, fireproof jackets for iron columns, furnace linings, safety warehouses, etc. The material from which it is made is clay mixed with resinous saw-dust. It is prepared into various shapes by passing through dies, allowed to dry, then baked at an intense heat in a kiln. The saw-dust burning out leaves the burned pieces porous. It may be planed, tongued, grooved, sawed, etc., into any desired shape.

The "Boiler Setting" of the Rich—Morrison Perfect Construction Company was also described and illustrated by lantern views. The object of the invention is to effect a more complete combustion of carbonaceous fuel and to suppress the smoke nuisance. This is sought to be accomplished by the admission of steam and air into the fire space in a peculiar manner. A special description of this device is in course of preparation for publication. Louis H. Spellier's "New Sparkless Current Breaker" was illustrated and described. This device is described in this number of the JOURNAL.

B. Frank Teal's "Portable Sectional Elevator and Projector," designed

to provide an efficient means of establishing communication with points difficult of access. Its most important use is as a means of establishing communication with burning buildings, whereby persons therein, for whose rescue all other means have failed, may be enabled to escape, or the firemen to ascend, as the requirements of the case may be. A special description of this device is in course of preparation for publication. Several oil paintings, in which luminous paint had beeen employed to give its well known and characteristic effects in the dark, were exhibited on the part of Messrs. Ayres & Williamson, of Philadelphia.

At the conclusion of the report a new lantern microscope, constructed by Mr. Zentmayer, from designs furnished by Mr. D. S. Holman, was presented to the Institute on behalf of a number of subscribers. The meeting thereupon adjourned to witness the capabilities of the apparatus, which embodies some new and ingenious features which are believed to make it superior, in many respects, to other instruments of the kind.

The President named the following Standing Committees of the Institute for 1883:

On the Library.—Chas. Bullock, Lewis S. Ware, Dr. Isaac Norris, Henry Pemberton, Jos. M. Wilson, Fred. Graff, Dr. W. Lehman Wells, Prof. Marks, Coleman Sellers, Jr., H. Carvill Lewis.

On Minerals.—Dr. F. A. Genth, Theo. D. Rand, Clarence Bement, Persifor Frazer, Dr. W. H. Wahl, Prof. E. J. Houston, Otto Lüthy, E. F. Moody, Dr. G. A. Koenig, H. Pemberton, Jr.

On Models.—C. Chabot, H. L. Butler, Edward Brown, M. L. Orum, J. Goehring, L. L. Cheney, J. J. Weaver, S. Lloyd Wiegand, N. H. Edgerton, Chas. J. Shain.

On Arts and Manufactures.—J. J. Weaver, George V. Cresson, Hector Orr, W. B. Le Van, Wm. Helme, J. S. Bancroft, Alfred Mellor, Cyrus Chambers, Jr., George Burnham, J. W. Nystrom.

On Meteorology.—Pliny E. Chase, Hector Orr, Dr. Isaac Norris, David Brooks, Jas. A. Kirkpatrick, Alex. Purves, Dr. W. H. Wahl, T. B. Maury, Prof. M. B. Snyder.

On Meetings.—Fred Graff, Washington, Jones, Chas. H. Banes, A. E. Outerbridge, Jr., W. L. Dubois, W. H. Thorne, Cyrus Chambers, Jr., J. J. Weaver, Addison B. Burk, Horace W. Sellers.

WILLIAM H. WAHL, *Secretary.*

JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXV. APRIL, 1883. No. 4.

PRELIMINARY REPORT OF THE SPECIAL COMMISSION TO INVESTIGATE THE WATER SUPPLY OF THE CITY OF PHILADELPHIA.

Philadelphia, October 14, 1882.

To the Select and Common Councils
of the City of Philadelphia.

GENTLEMEN:—The undersigned, having been appointed by his Honor the Mayor, in conformity with the ordinance approved June 7, 1882, authorizing him to appoint a Board of Experts, to "report to Councils the methods pursued in the Water Department, together with their recommendations of what should be done for the present and future supply of the City, with such itemized estimates as will enable the cost to be determined," have the honor to state, that they met September 19th, and have been continuously engaged in examining and studying the subject; that the problem presented to them is of so large, complex, and important a character, that they are unable at this time to report upon the future supply; but that their examinations thus far have revealed a condition of affairs in regard to the present supply of water to the City, which does not justify delay upon their part in presenting this partial report for the consideration of your honorable bodies.

They find that in supplying the lower levels of the City the existing

machinery has been worked to its utmost capacity; that at the two largest steam works there is no spare machinery, and in two others the whole supply depends upon one engine in each. They also find that at the rate of annual increase in largest consumption of the past year (which is about eleven (11) million gallons daily) there will not be enough pumping power to sufficiently supply, during the driest seasons of next year, an area which contains two-thirds of the population, while in 1884 there will be a short supply throughout almost the whole City.

Nor can an abundant flow of water in the Schuylkill be relied on to avert this catastrophe next year; for not only is such a flow, when it is most needed, unlikely, but the amount which could then be furnished by the Fairmount wheels is to the lower levels only, and would be entirely inadequate to supply the deficiency.

Indeed, the time has come, when it is necessary to face the fact that during periods of least flow of water, which are also those of greatest consumption, the water power at Fairmount is practically unavailable.

It is also to be noted that machinery is not always in good working order. Pumping engines and boilers must be stopped for repairs, and accidents occur to engines and pumps, and from breakage of mains. For these reasons it is customary in other cities, where there is abundant reservoir capacity, to add at least one-third to the pumping power which is ordinarily needed at periods of the greatest consumption.

Your Board regard the following named machinery and appliances as imperatively needed for the supply of water to the City in the summer of 1883. In their opinion, none of them can be dispensed with, except at the risk of serious results, in the localities supplied by the specified pumping stations.

I. FOR SCHUYLKILL WORKS.

Two (2) Fifteen million gallon engines to pump, one against 150 feet, one against a higher head	$96,000
Two (2) ranges of boilers and connections	60,000
Two (2) forcing mains	30,000
Completing 48-inch main partly laid	14,000
Boiler and engine house	40,000
Foundation for same	10,000
Total	$250,000

II. FOR ROXBOROUGH WORKS.

One (1) Seven and a half million gallon engine to pump against 360 feet head, with forcing main in house....	$50,000
Removing old and substituting two boilers and connections..	7,000
New inlet, screen, and dredging..............................	3,000
Total	$60,000
Distributing main to supply Germantown, from Mt. Airy Reservoir to Manheim, on Green........................	$70,000

III. FOR FRANKFORD WORKS.

One (1) Ten million gallon engine and connections, to pump against 200 feet..	$45,000

As to the character of the machinery to be obtained the estimates given for the engines refer to the "Worthington Compound Duplex," which the Board consider to be reliable, comparatively free from liability to serious accident, not expensive in first cost and maintenance, and fairly economical in fuel. To supply an emergency like the present, where time for construction and erection is extremely short, they know of no other type which, on the whole, presents so many advantages.

In regard to boilers, they recommend and have estimated for the cylindrical, tubular at Roxborough Works, like those just bought; and for Schuylkill Works marine tubular boilers,which, although of greater first cost, present certain important advantages in preparing for an emergency, and are at least equal to the others in the economy of fuel and repairs.

Your Board have reason to believe that if the above recommendations are adopted, and contracts for the machinery are entered into before December 1st next, that two of the engines can be used by June 1, 1883, and the other two by August 1st of the same year, although the time is short, both for consideration of the subject, and the execution of the work.

Your Board are satisfied of the great importance of an early completion of the East Park Reservoir, entire, with its connecting, forcing, and distributing mains; and of building a reservoir at Cambria and Thirtieth streets; and of adding to that at Mount Airy. For both of the latter, land should be acquired at once. All of them are needed now, and will ultimately form proper centres of distribution, whatever may be the permanent source of supply for the City.

The importance of reservoirs is due not only to the necessity for subsidence, but also to guard against the results of serious accidents, such as the experience of this and other cities shows are liable to occur.

The appropriations for these reservoirs are next in importance to those for the machinery, for which estimates have been given.

Expenditures under such appropriations would extend over a period of at least three years, 1883 to 1885. The following estimates of probable cost are believed to be sufficiently accurate to be a basis for appropriation :

I. EAST PARK RESERVOIR AND CONNECTIONS.

Completing two basins	$400,000
" the third basin	300,000
Forcing mains	126,000
Distributing mains	371,200
Total	$1,197,200

II. CAMBRIA RESERVOIR AND CONNECTIONS.

Land, say	$100,000
150,000,000 gallon reservoir	375,000
Forcing and connecting mains	240,000
Distributing main (one)	105,000
Total	$820,000

III. MT. AIRY RESERVOIR.

Land, say	$25,000
75,000,000 gallon reservoir	225,000
Total	$250,000

Of these amounts there should be expended—

In 1883, at East Park, finishing small basin and work on others	$372,500
Cambria, land and work	200,000
Mount Airy, land and work	75,000
Total, first year	$647,500

In 1884, at East Park, finishing second basin and work on other, and main	$340,000
Cambria, work on basin and main	325,000
Mount Airy, work on basin	100,000
Total, second year	$765,000
In 1885, at East Park, finishing basins and mains	$484,700
Cambria, " " " "	295,000
Mount Airy, finishing basin	75,000
Total, third year	$854,700

In considering the question of "present supply," it should be borne in mind that at least five years must elapse before a gravity system, such as contemplated by the Perkiomen or Delaware projects, could be accomplished. At least one year would be spent in making surveys, plans, and detailed specifications. Their discussion and adoption would consume another year, at least; and the construction of the works would take three or four years more, supposing that the funds for so large an undertaking could be provided in that time.

This is a sufficient reason for providing for an adequate water supply by steam pumping machinery and by storage in reservoirs, up to 1888. Long before that time, if the present rate of increase of demand prevails, the consumption of water will become so large as to demand a still further increase than has been recommended in this report, both in pumping power and in distributing facilities, which are now in many localities far below the demand. A consideration of these points may, however, be safely left for the final report of this Board.

Meanwhile your attention is respectfully called to the fact that complete surveys must be made, and reliable data obtained, of the localities from which and through which a pure water supply can be drawn, in order to form a correct judgment as to their availability. As it is essential that this information be obtained, an appropriation for such surveys of not less than fifteen thousand dollars ($15,000) is suggested.

With regard to the management of the pumping stations, your Board would call attention to the system which is now, and has been since the earlier days of the Department, the prevailing one, as being radically wrong.

At each of these stations there are now two engineers of equal authority, who are on duty alternately during the day and the night.

Thus there can be no definite responsibility or uniformity of management.

The Board recommend that this organization be so modified as to place one superior engineer in charge of each station. In the two larger stations—Schuylkill and Belmont—he should not be required to take a watch, but have two competent assistants. At the other works he might take a watch and have one assistant. He should, in all cases, be responsible only to the head of the Department, and should maintain discipline, receipt for supplies, provide spares, supervise repairs or any additional construction going on, and direct the proper use of the machinery. Such men should be paid good salaries, commensurate with their qualifications and the responsibility placed upon them.

The Board also consider that the salaries now paid to engineers, corresponding to those of the assistants under the proposed plan, being less than those of good mechanics, in proportion to the time they are on duty, and far below those paid in other cities for similar work, are insufficient to command and keep the best men. They believe that the saving in fuel alone which would result from these changes would more than pay the extra amount required for wages, and that greater security would be obtained.

They also suggest that the several pumping stations and reservoirs should be connected together and with the Purveyor's and central office by telephonic communication, the immense value of which at all times, and especially in case of accidents, is obvious.

The Board have been deeply impressed with the vital necessity of keeping out of the inlets to different pumping wells a large and constantly increasing amount of offensive sewage. They believe that this great evil, so far as it proceeds from the sewer that empties into the Schuylkill river at the east end of Girard avenue bridge, can be abated at an early day, and at a cost small in comparison with the importance of the object.

This, however, belongs to the Survey Department of the City, which has also under consideration methods for keeping the sewage of Manayunk and the points below it out of the river above Fairmount dam.

This is a necessity which cannot be too soon provided for, considering the importance of restoring the water supply to its original purity, and, at the same time, of protecting the great industries of that section.

Appended to this report, the Board submit a table showing the pumping capacity and consumption for a series of years; also a table showing the organization and wages paid in different cities.

Respectfully submitted.

E. S. CHESBROUGH,
J. VAUGHAN MERRICK,
FRED. GRAFF.

WM. H. MCFADDEN, *Chief Eng. Water Dept.*

Table showing the available capacity of Works of Philadelphia Water Department, in millions of gallons per day, from 1872 to 1883, at time of maximum demand, the reserve engines at time of accident or break down of machinery, and the probable deficit for 1883.

Year.	Steam power. M. g. p. d.	Water power. M. g. p. d.	Total. M. g. p. d.	Demand. M. g. p. d.	Reserve engines unavailable.*	Deficit. If no accident.	Deficit. If an accident to the largest engine.
1872	41	15	56	45	10	....	....
1873	43	15	58	49	10	....	....
1874	43	15	58	50	10	....	....
1875	43	15	58	52	10	....	....
1876	47	15	62	62	10	....	....
1877	47	22	69	57	25	....	....
1878	60½	20	80½	64	14	....	....
1879	59½	7½	67	65	14	....	6
1880	59½	7½	67	67	14	....	6
1881	74	5	79	75	9	....	11
1882	74	13½	87½	86	9	....	11
1883	74	5	79	100	9	21	32

NOTE.—If the large engine at Frankford breaks down, there will be a short supply at Frankford; and if the larger engine at Roxborough or its boilers break down, a failure at Germantown will be the result.

* Unavailable on account of want of boilers or pumping main.

Cities	St. Louis.		Brooklyn.		Cincinnati.		Philadelphia.	
Pumping stations	......	......	Ridgewood		Main Works.		Spring Garden.	
Lift in feet	$\frac{230+40}{2}$	135	171		171		134	
Max. mill's gall's into reservoir	35+2	70	37		37		45	
Max. work mill's gall's 100 feet high	......	94·50	63·27		63·27		60·30	
	No.	Pay per day.	No.	Pay per day.	No.	Pay per day.	No.	Pay per day.
Engineers in charge	1	$6.95	1	$6.85.	1	$5.00	2	$2.46.
Assistant engineers	9	4.50 3.33 4.16 3.17 3.80 3.00 3.50 2.80 2.60	8	3.61 to 3.28	5	3.50	......	None
Oilers	6	2.00	5	2.05	10	2.00	8	1.90
Firemen	24	2.00 1.83	16	1.97	13	2.00	10	1.90
Coal passers	20	1.66	6	1.81	6	2.00	4	1.90
Gaugemen	......	None.	......	None	......	None	2	1.90
Laborers	......	Not specified	6	1.75	......	Not specified	1	1.75
Coal weighers	......	......	......	......	3	3.00 2.00	......	......
Clerks	......	......	......	......	1	3.00	1	1.90
Flue cleaners	......	......	......	......	1	1.75	......	......
Total wages per diem	60	$128.97	42	$97.54	40	$92.25	28	$54.17
Cost of labor per million gallons lifted 100 ft. high	......	$1.36	......	$1.54	......	$1.45	......	.90c.

NOTE.—At St. Louis the water is first pumped from the Mississippi river, 40 feet, into settling basins; from thence into the distributing reservoir, 230 feet high; the average lift being 135 feet for double the consumption of 35,000,000 gallons, or 70,000,000 gallons 135 feet high $=94\frac{1}{2}$ million gallons 100 feet high.

Cities	Louisville.		Chicago.		Philadelphia.	
Pumping stations			West Side		Belmont.	
Lift in feet	175 ft.		100 ft.		212 ft.	
Maximum millions gallons into reservoir	11 mill's		30 mill's		18 mill's	
Maximum work millions gallons 100 feet high	19·25		30·00		38·16	
	No.	Pay per day.	No.	Pay per day.	No.	Pay per day.
Engineers in charge	1	$5.00	1	$6.85	2	$2.46
Assistant engineers	3	4.52 4.31 1.61	3	4.39	......	None
Oilers	2	2.18	4	2.13	4	1.90
Firemen	2	2.18	6	2.23 2.13	10	1.90
Coal passers	2	2.18	3	1.97	4	1.90
Gaugemen	......	......	......	......	2	1.90
Laborers	......	......	......	......	1	1.75
Coal weighers	1	2.18	1	2.13	......	None
Clerks	......	......	......	......	1	1.90
Flue cleaners	......	......	2	2.13 1.97	......	......
Total wages per diem	11	$30.70	20	$53.76	24	$46.57
Cost of labor per million gallons lifted 100 feet high	......	$1.59	......	$1.79	......	$1.22

ON THE APPLICATION OF THE PRINCIPLE OF VIRTUAL VELOCITIES TO THE DETERMINATION OF THE DEFLECTION AND STRESSES OF FRAMES.

By George F. Swain, S.B.
Instructor of Civil Engineering in the Massachusetts Institute of Technology, Boston, Mass.

(Concluded from page 204.)

We may show here, however, how the continuous girder may be treated in a rather different manner from that explained in the previous pages. We will confine ourselves to the case represented in figure 11, the web system being simple, in which case the structure is statically determined as regards the inner forces. As regards the outer forces it is undetermined, there being $n—1$ equations failing. But it is clear that if we omit the chord pieces over each point of support, as in the figure, we reduce the structure to n simple girders, and it becomes in every way statically determined. Our problem is thus reduced to finding the $n - 1$ stresses S', S'', S''', etc., in the chord pieces over the piers, and this problem may be solved by a method exactly analogous to that pursued in treating trusses with superfluous bars, for in this case the chord pieces referred to are superfluous, and by removing them the system becomes statically determined. The only difference in the two cases is, that before the system was already statically determined regarding the *outer* forces, and was made so regarding the *inner* forces by removing the superfluous bars; while here, the system is already statically determined regarding the *inner* forces, and is made so regarding the *outer* forces by removing those bars. The method of treatment is in both cases precisely the same. We have, if we apply at A and B, acting towards each other, and hence representing tension, forces equal to unity, for the shortening of AB.*

$$\Delta\lambda_2 = \Sigma\, u''\, \Delta l,$$

u_1'', u_2'', u_3'', etc., being the stresses produced in the bars of the (statically determined) system by the forces unity in A and B, and Δl_1, Δl_2, Δl_3, etc., being the changes in length of those bars. If, as before, the stresses produced in the necessary bars by the given applied loads be

* The upper chord joints on each side of R_3 should be lettered A and B.

called Y_1, Y_2, Y_3, etc. (which may be found by statics alone), then the real stresses S_1, S_2, S_3, etc., in those bars are given by the following equations, as before:

$$\left.\begin{aligned} S_1 &= Y_1 + u_1'S' + u_1''S'' +, \text{etc.}, \\ S_2 &= Y_2 + u_2'S' + u_2''S'' +, \text{etc.}, \end{aligned}\right\} \qquad (39)$$
$$\text{etc., etc.}$$

Remembering now that a force in $A\ B$ affects only the bars in the two adjacent spans, and that therefore u' exists only for the bars in the first and second spans, u'' only for those in the second and third, and so on, we have

$$\left.\begin{aligned} -K'\,S' &= \Sigma^{1,2}\,u'\,K\,S \\ -K''\,S'' &= \Sigma^{2,3}\,u''\,K\,S \\ -K'''\,S''' &= \Sigma^{3,4}\,u'''\,K\,S \end{aligned}\right\} \qquad (41a)$$

the numbers above the sign of summation denoting the spans over which the summation is to extend. If we substitute now in these equations the values of S, etc., from equations (39), we have the following, due regard being paid to the above remark regarding the spans considered:

$$\left.\begin{aligned} o &= K'\,S' + \Sigma^{1,2}\,u'\,K\,Y + S'\,\Sigma^{1,2}\,u'^2\,K + S''\,\Sigma^2\,u'\,u''\,K \\ o &= K''\,S'' + \Sigma^{2,3}\,u''\,K\,Y + S'\,\Sigma^2\,u''\,u'\,K + S''\,\Sigma^{2,3}\,u''^2\,K + \\ &\qquad S'''\,\Sigma^3\,u''\,u'''\,K \\ o &= K'''\,S''' + \Sigma^{3,4}\,u'''\,K\,Y + S''\,\Sigma^3\,u'''\,u''\,K + S'''\,\Sigma^{3,4} \\ &\qquad u'''^2\,K + S^{\text{iv}}\,\Sigma^4\,u'''\,u^{\text{iv}}\,K \end{aligned}\right\} \qquad (44)$$

etc.

These equations are equal in number to the superfluous bars, there being one for each pier. From them we can obtain by elimination the values of the unknown quantities S', S'', S''', etc., and the problem is solved, the true stresses S_1, S_2, etc., being found by equations (39). In case the arrangement of the bars is not as represented in the figure, it is easy to see which bar shall be considered superfluous, and further explanation is scarcely necessary. We will only now show how the above equations, which are very much more general than those derived from the Theorem of Three Movements, reduce to the latter in a particular case. Suppose the girder to have a constant moment of inertia, and let us neglect the influence of the web members. Let each chord have a section F. Let the second and third spans be loaded uniformly with q_2 and q_3 pounds per running foot. Let distances, in either span, from the second pier, be called x. Then the number of joints in each chord is to be considered infinitely large, and the length of each chord

piece is dx. Hence $K = \frac{dx}{EF}$. The values of the different quantities in the second equation (44) will be found to be as follows:

2d Span. Upper chord.

$$\begin{cases} Y = -\dfrac{q_2\, x\,(L_2 - x)}{2h} \\[2ex] u' = +\dfrac{1\,.\,h}{L_2}\,.\,\dfrac{x}{h} = +\dfrac{x}{L_2} \\[2ex] u'' = +\dfrac{1\,.\,h}{L_2}\,.\,\dfrac{L_2 - x}{h} = +\dfrac{L_2 - x}{L_2}. \end{cases}$$

Lower chord.

$$\begin{cases} Y = +\dfrac{q_2\, x\,(L_2 - x)}{2h} \\[2ex] u' = -\dfrac{x}{L_2} \\[2ex] u'' = -\dfrac{L_2 - x}{L_2} \end{cases}$$

3d Span. Upper chord.

$$\begin{cases} Y = -\dfrac{q_3\, x\,(L_3 - x)}{2h} \\[2ex] u'' = +\dfrac{1\,.\,h}{L_3}\,.\,\dfrac{L_3 - x}{h} = +\dfrac{L_3 - x}{L_3} \\[2ex] u''' = +\dfrac{1\,.\,h}{L_3}\,.\,\dfrac{x}{h} = +\dfrac{x}{L_3} \end{cases}$$

Lower chord.

$$\begin{cases} Y = +\dfrac{q_3\, x\,(L_3 - x)}{2h} \\[2ex] u'' = -\dfrac{L_3 - x}{L_3} \\[2ex] u''' = -\dfrac{x}{L_3} \end{cases}$$

The sign of summation in equation (44) becomes a sign of integration, and the values of the different terms are as follows:

$$K''\, S'' = S''\, \frac{dx}{EF} \tag{45}$$

$$\left.\begin{array}{l} \Sigma^{2.3}\, u''\, K\, Y = -\int_o^{L_2} 2 \,.\, \left(\frac{L_2 - x}{L_2}\right)\left(\frac{dx}{EF}\right)\left[\frac{q_2\, x\,(L_2 - x)}{2h}\right] \\ -\int_o^{L_3} 2 \,.\, \left(\frac{L_3 - x}{L_3}\right)\left(\frac{dx}{EF}\right)\left[\frac{q_3\, x\,(L_3 - x)}{2h}\right] = - \frac{1}{EFh} \\ \left\{ \frac{q_2}{L_2} \int_o^{L_2} (L_2 - x)^2\, x\, dx + \frac{q_3}{L_3} \int_o^{L_3} (L_3 - x)^2\, x\, dx \right\} \\ = - \frac{q_2\, L_2^3 + q_3\, L_3^3}{12\,.\, EFh} \end{array}\right\} \quad (46)$$

$$\left.\begin{array}{l} S'\, \Sigma^2\, u''\, u'\, K = + S' \left\{ \int_o^{L_2} 2 \,.\, \frac{x\,(L_2 - x)}{L_2^2} \,.\, \frac{dx}{EF} \right\} = \\ + \frac{S'\, L_2}{3EF} \end{array}\right\} \quad (47)$$

$$\left.\begin{array}{l} S''\, \Sigma^{2,3}\, u''^2\, K = + S'' \left\{ \int_o^{L_2} 2 \,.\, \frac{(L_2 - x)^2}{L_2^2} \,.\, \frac{dx}{EF} + \right. \\ \left. \int_o^{L_3} 2 \,.\, \frac{(L_3 - x)^2}{L_3^2} \,.\, \frac{dx}{EF} \right\} = + \frac{2\, S''\, (L_2 + L_3)}{3EF} \end{array}\right\} \quad (48)$$

$$\left.\begin{array}{l} S'''\, \Sigma^3\, u''\, u'''\, K = + S''' \left\{ \int_o^{L_3} 2 \,.\, \frac{x\,(L_3 - x)}{L_3^2} \,.\, \frac{dx}{EF} \right\} = \\ + \frac{S'''\, L_3}{3EF} \end{array}\right\} \quad (49)$$

Substituting these values, the second of equations (44) becomes

$$o = - \frac{q_2\, L_2^3 + q_3\, L_3^3}{12EFh} + \frac{S'\, L_2}{3\, EF} + \frac{2\, S''\, (L_2 + L_3)}{3EF} + \frac{S'''\, L_3}{3EF} \quad (50)$$

The moment, M_2, at the first pier is $S'\, h$; that at the second pier is $M_3 = S''\, h$: hence (50) becomes

$$M_2\, L_2 + 2\, M_3\, (L_2 + L_3) + M_4\, L_3 = \tfrac{1}{4}\,(q_2\, L_2^3 + q_3\, L_3^3) \quad (51)$$

which is the general form of the theorem of three moments for the case of a uniform load.

The method above given clearly solves, then, the difficulty sometimes urged against the continuous girder, viz.: that it cannot be accurately calculated, taking account of a variable moment of inertia and a varying modulus of elasticity in different bars. As far as theoretical treatment goes, the continuous girder presents no difficulty, but practically the objections against it are so strong as to make it undesirable except in rare cases.

VIII. Historical and Critical.

The original articles upon the method which has formed the subject of the preceding pages are for the most part scattered through the various scientific periodicals; and the writer cannot pretend to be able to give a complete account of the history and bibliography of the subject; but with the hope that it may be of some interest and benefit to those who are less acquainted with the matter than himself, he ventures to add to the foregoing account the following brief notes.

The principle of virtual velocities, and the resulting principle that the work done by the outer forces, applied to any structure, equals that done by the inner forces, has long been recognized. It follows at once, too, from the principle of the conservation of energy. Its application to framed structures, however, is of comparatively recent date. The first writer who gave any such application, so far as I know, was Lamé, in his "Leçons sur la Théorie Mathématique de l'Elasticité des Corps Solides," published at Paris in 1866. In the seventh Leçon of this work Lamé applies the method to the determination of deflection, deducing, as we have done on a previous page, the equation

$$\frac{1}{2} P\varDelta = \frac{s^2 l}{2FE},$$

P being the force applied to a given point of a frame, $\varDelta$ the deflection of that point in the direction of P, s the stress caused thereby in a bar of length l and section F. From this follows

$$\varDelta = \frac{t\,s\,l}{FE},$$

t being the stress when $P = 1$. If all the bars are elastic, the resulting value of $\varDelta$ given by Lamé is substantially the same as our equation (3). He transforms his equation into another no more convenient for use, but puts $\frac{s}{F}$ constant, which is evidently incorrect, inasmuch as the same loading will not cause the maximum stresses in all the bars. He applies his method to a triangular frame, like our figure (5). Lamé does not seem to have fully grasped the importance and generality of the method, for he limits his discussion to finding the deflection of the point where a given load is applied, and does not show how the deflection of any point in any direction under any loading may be found.

The next author who discussed and applied the method, so far as I know, was Maxwell, who, in an article "On the Calculation of the

Equilibrium and Stiffness of Frames," in the "Philosophical Magazine," for April, 1864, treated the subjects of deflection and of frames with superfluous bars. He showed first the conditions under which frames are statically determined, deducing the equation $n = 2m - 3$; he then demonstrates a theorem which is essentially that embodied in the equation $\varDelta = t \,.\, \varDelta l$, for any one bar; he then proceeds to discuss frames with superfluous bars, and deduces equations which are identical with those which we have given for this case; finally, he proceeds to find a formula for the deflection of a certain point of a Warren girder, finding separately that due to the web and that due to the chords, assuming in each case the stress per square inch to be the same in all the bars. This is of course incorrect; and in fact, it is useless to attempt to deduce any general formulæ of this kind. Maxwell discussed no other applications of the method, leaving untouched the important subject of the arch.

In the article "Bridges," in the Encyclopœdia Britannica, Professor Jenkin gave a short paragraph on the application of the method to arches hinged at the springing, and deduced an equation for the horizontal thrust identical with our equation (4). He gave no other applications.

To Professor Mohr, of Dresden, is due the credit of making the method known in Germany, as well as that of making several important additions. In the "Zeitschrift des Architekten- und Ingenieur-Vereins zu Hannover," for 1874 and 1875, will be found an article by him entitled "Beitrag zur Theorie des Fachwerks," in which he first discusses geometrically the condition under which frames are statically determined, treats the subject of deflection about as we have treated it, but adding nothing new to what previous writers had given, treats frames with superfluous bars, applying his results to several examples, and finally proceeds to treat the continuous girder. He gives the method which we have explained last (Fig. 11), and shows, as we have done, the agreement of the resulting formulæ with those obtained from the application of the Theorem of Three Moments. He states that, judging from several calculated examples, the assumption usually made, that the moment of inertia of the section of the girder is constant, is allowable. He calls attention to the difficulty attending the use of the method, viz., the tedious arithmetical calculations involved, and finally treats the whole subject graphically, developing a beautiful graphical method for finding the deflection of any point of

a girder, and giving a method of finding the stresses in the continuous girder by a process which consists in adding the ordinates of a polygon which he shows how to construct. Mohr calculates an example by this graphical method.

The arch with hinges at the springing was treated by Mohr in an article "Beitrag zur Theorie des Bogenfachwerkträger," in the same periodical, for 1874.

The next author to treat this method was Professor Winkler, of Berlin, in an article "Beitrag zur Theorie der Bogenträger," in the "Zeitschrift des Architekten- und Ingenieur-Vereins zu Hannover," for 1879. Winkler deduced our equation (4) for an arch hinged at springing, gave many other details connected with the calculation of such an arch, treated briefly the arch hinged at the crown, and also gave a treatment of the arch without hinges, which we have followed in the previous pages. In his book entitled "Innere Kräfte gerader Träger," Winkler discusses frames with superfluous bars, according to "Mohr's method," as he names it, though it really is Maxwell's. In fact, the matter seems to be generally attributed in Germany to Dr. Mohr, Maxwell's contributions being never referred to.

The only reference to the method in American literature, so far as I know, is in Professor Greene's book on Arches, chapter 12, where a method is given which, it is stated, is to be found in "The Engineer," for Feb. 10, 1873, and also in the Encyclopædia Britannica—article "Bridges." The first reference, however, is incorrect. Professor Greene's method, although amounting to the same as that given in Jenkin's article already referred to, is not exactly the same in principle; it is founded, not on the principle of virtual velocities, or of work, but on that of the instantaneous axis. The formula for H, however, is essentially identical with our equation (4). The detailed treatment of the arch by the same method, founded on the principle of the instantaneous axis, was given by Professor Fränkel, of Dresden, in "Der Civilingenieur," for 1875,* where the reference is made to the first theory of the framed arch hinged at springing, in which the change of length of each bar is taken into account, given by G. F. Schultze, in the "Zeitschrift des Vereins deutscher Ingenieure," for 1865, page 536. In this article the change of span is found by geometrical

*"Anwendung der Theorie des augenblicklichen Drehpunktes auf Bogenträger. Theorie des Bogenfachwerks mit zwei Gelenken."

methods, and the method used is complicated compared with that explained above.

Various other writers could be named who have written on this subject, but none who have added any new points, except in the details of application to particular cases.

The method which has been explained, supposes for its application the sections of all the bars of the frame to be given. In calculating a frame, these sections are what we wish to determine. The method given does not, therefore, dispense with a preliminary approximate calculation, according to the usual method, or others which may be deemed sufficiently accurate. It simply affords an exact solution of the problem, while the results given by the ordinary methods are more or less incorrect. In any case, the approximate sections must first be calculated. This may be easily done, in some cases, by assuming a hinge at some particular point; thus in the case of an arch with straight upper chord, curved lower chord, hinged at the abutments, and with a small depth at the crown, a hinge may be assumed at the latter point, and the stresses calculated approximately without resort to elastic conditions. In the case of the arch without hinges and with parallel chords, the usual method of computation, assuming a constant cross-section and neglecting the effect of the web on deflection, may be used as a first approximation; then the method which we have explained may be applied as many times as necessary, but usually one application will be sufficient to obtain the requisite accuracy.

At the commencement of this article we distinguished the elastic deflection from the non-elastic deflection. Thus far we have only considered the former. The question now arises, does the latter, which cannot be calculated, affect the accuracy of the method we have discussed? Unfortunately it does, for the equation (2) gives the deflection of any point due to a change of length $\varDelta l$ of one bar, due to any cause whatever. If the change of length is non-elastic and due to imperfect fitting, the deflection is non-elastic, but is none the less present. In the case of an arch, if any bar in the top chord (Fig. 7) becomes shorter on account of imperfect fit, the span is evidently increased and a horizontal thrust must exist, due to that cause alone, if the span is to be kept constant. If a frame is statically determined, both as regards the outer and inner forces, the non-elastic deflection is without effect on the stresses; for a consideration of deflection does not enter into their determination. Among non-elastic deflections we may include changes of length due

to changes of temperature, and to settling of the piers or abutments. If the non-elastic deflections are known, their effect may be calculated. The non-elastic deflections due to imperfect fitting of the parts, and to settling of piers and abutments can never be exactly known; that due to temperature may be allowed for as follows: Take first the case of the arch hinged at springing; if the temperature rises or falls by θ degrees, and the coefficient of expansion of the structure is a, then the change of span under vertical reactions would be $\pm L\,a\,\theta$. The horizontal thrust necessary to counterbalance this change of span is given by the equation.

$$\pm L\,a\,\theta = H \Sigma \frac{t^2\,l}{F\,E}, \text{ or}$$

$$H = \pm \frac{L a\,\theta}{\Sigma \frac{t^2\,l}{F\,E}} \tag{52}$$

t being the stress produced in a bar by a force unity acting either outwards or inwards at the springing. The value of H calculated by equation (4) is liable to be increased or diminished by the value in equation (52), if θ is the change of temperature above or below a mean temperature, at which there is no stress due to this cause. As the value of θ may be 50 or 60 degrees, this change may become considerable. Other cases may be treated similarly, but it will be better to take into consideration the change of length $\theta\,a\,l$ of each bar. Thus equation (52) might be written

$$H = \pm \frac{\Sigma\, t\,l\,\theta\,a}{\Sigma \frac{t^2\,l}{F\,E}} = \pm\,\theta a\,\frac{\Sigma\, t\,l}{\Sigma \frac{t^2\,l}{F\,E}} \tag{52a}$$

Similarly in any other case we have only to find the stresses due to changes of length $\theta\,a\,l$ of the bars.

The fact that statically undetermined systems cannot be exactly calculated, and are liable to have their calculated stresses changed by an uncertain amount on account of non-elastic deflections, constitutes the principal objection that can be urged against them. Difficulty of calculation would have little weight, if a saving of material were to be effected by their use; but the uncertainty attending them renders necessary a larger factor of safety and more carefully constructed piers and abutments, while the true state of stress can never be exactly known. The disfavor into which continuous girders have fallen in almost all countries except France is, therefore, no doubt justified; and

of the various forms of the arch, that with three hinges is to be preferred. If there is one element which a structure should possess, it is certainty in regard to the forces which are exerted in it. No refined calculations as to saving of material can be weighed in the balance against indeterminate stresses. In a few cases it can be shown that the uncertainty is small—that the limits of error are narrow; in these cases practical considerations may point to the adoption of a statically undetermined system. While the writer, therefore, is no advocate of the indiscriminate use of the statically undetermined systems—of the continuous girder, and of arches with fewer than three hinges—he nevertheless hopes in these pages to have brought to the attention of some who may have been unacquainted with them, some methods and considerations which are as beautiful as they are valuable and interesting.

ERRATA—Page 112, 1st line from bottom, for $H_2\ L f\ V_2$ read $H_2 = f\ V_2$. Page 115, 13th line from top, for $\frac{Z}{h}$ read $\frac{z}{h}$. Page 196, 13th line from top, for $\sum_r \frac{h_r\ S l}{F E}$ read $\sum_r \frac{v_r\ S l}{F E}$. Page 198, 4th line from bottom, for x read d. Page 201, 7th line from top, for R_n read $-R_n$. Page 204, 6th line from top, for $u^{2\prime\prime}$ read $u_2^{\prime\prime}$.

Observations of the Solar Spectrum.—One of the objects of Langley's expedition to Mount Whitney, in 1881, was to obtain a new determination of the solar constant, or the quantity of heat sent to the earth, and to ascertain incidentally the laws of the absorption of solar rays by the atmosphere. Pouillet's classical value is about 1·7 calories. Later determinations tend to increase this value; those of Soret, Crova, and Violle indicate from 2·2 to 2·5 calories. On account of the great number of observations and the long calculations which they require, Langley has not yet given a final estimate, but he finds that it will be about three calories; in other words, were it not for our atmosphere, the solar rays would heat one gramme of water three degrees C. per minute, for each square centimetre of the earth's surface which was normally exposed to it. His observations show that only a fourth of the energy which vivifies the world is found in the visible and ultra violet portions of the spectrum. On eliminating the effects of atmospheric absorption, he infers that the absolute color of the photosphere is blue.—*Comptes Rendus*, xcv, 482. C.

THE ATTITUDES OF ANIMALS IN MOTION.

By EADWEARD MUYBRIDGE, of San Francisco.

[A lecture delivered before the Franklin Institute, February 13th, 1883.]

The problem of animal mechanism has engaged the attention of mankind during the entire period of the world's history.

Job describes the action of the horse; Homer, that of the ox; it engaged the profound attention of Aristotle, and Borelli devoted a lifetime to its attempted solution. In every age and in every country, philosophers have found it a subject of exhaustless research. Marey, the eminent French savant of our own day, dissatisfied with the investigations of his predecessors, and with the object of obtaining more accurate information than their works afforded him, employed a system of flexible tubes, connected at one end with elastic air-chambers, which were attached to the shoes of a horse; and at the other end with some mechanism, held in the hand of the animal's rider. The alternate compression and expansion of the air in the chambers caused pencils to record upon a revolving cylinder the successive or simultaneous action of each foot, as it correspondingly rested upon or was raised from the ground. By this original and ingenious method, much interesting and valuable information was obtained, and new light thrown upon movements until then but imperfectly understood.

While the philosopher was exhausting his endeavors to expound the laws that control and the elements that effect the movements associated with animal life, the artist, with a few exceptions, seems to have been content with the observations of his earliest predecessors in design, and to have accepted as authentic without further inquiry, the pictorial and sculptural representations of moving animals bequeathed from the remote ages of tradition.

When the body of an animal is being carried forward with uniform motion, the limbs in their relations to it have alternately a progressive and a retrogressive action, their various portions accelerating in comparative speed and repose as they extend downwards to the feet, which are subjected to successive changes from a condition of absolute rest, to a varying increased velocity in comparison with that of the body.

The action of no single limb can be availed of for artistic purposes without a knowledge of the synchronous action of the other limbs; and to the extreme difficulty, almost impossibility, of the mind being

capable of appreciating the simultaneous motion of the four limbs of an animal, even in the slower movements, may be attributed the innumerable errors into which investigators by observation have been betrayed. When these synchronous movements and the successive attitudes they occasion are understood, we at once see the simplicity of animal locomotion, in all its various types and alternations. The walk of a quadruped being its slowest progressive movement would seem to be a very simple action, easy of observation and presenting but little difficulty for analysis, yet it has occasioned interminable controversies among the closest and most experienced observers.

When, during a gallop, the fore and hind legs are severally and consecutively thrust forwards and backwards to their fullest extent, their comparative inaction may create in the mind of the careless observer an impression of indistinct outlines; these successive appearances were probably combined by the earliest sculptors and painters, and with grotesque exaggeration adopted as the solitary position to illustrate great speed. Or, as is very likely, excessive projection of limb was intended to symbolize speed, just as excess in size was an indication of rank. This opinion is to some extent corroborated by the productions of the Grecian artists in their best period, when their heroes are represented of the same size as other men, and their horses in attitudes more nearly resembling those possible for them to assume. The remarkable conventional attitude of the Egyptians, however, has, with few modifications, been used by artists of nearly every age to represent the action of galloping, and prevails without recognized correction in all civilized countries at the present day.

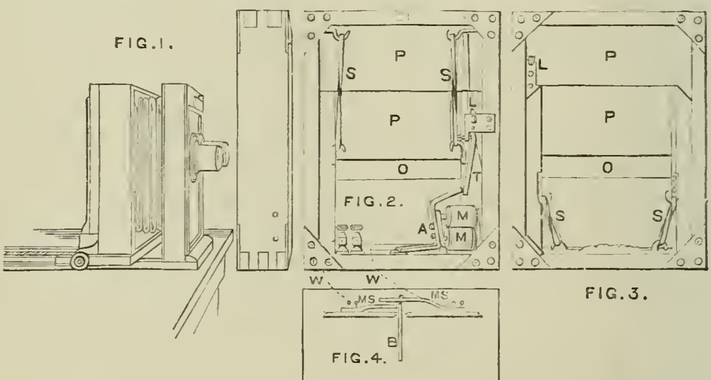
The ambition and perhaps also the province of art in its most exalted sense, is to be a delineator of impressions, a creator of effects, rather than a recorder of facts. Whether in the illustrations of the attitudes of animals in motion the artist is justified in sacrificing truth, for an impression so vague as to be dispelled by the first studied observation, is a question perhaps as much a subject of controversy now as it was in the time of Lysippus, who ridiculed other sculptors for making men as they existed in nature; boasting that he himself made them as they ought to be.

A few eminent artists, notable among whom is Meissonier, have endeavored in depicting the slower movements of animals to invoke the aid of truth instead of imagination to direct their pencil, but with little encouragement from their critics; until recently, however, artists

and critics alike have necessarily had to depend upon their observation alone to justify their conceptions or to support their theories.

Photography, at first regarded as a curiosity of science, was soon recognized as a most important factor in the search for truth, and its more popular use is now entirely subordinated by its value to the astronomer, the anatomist, the pathologist, and other investigators of the complex problems of nature. The artist, however, still hesitates to avail himself of the resources of what may be at least acknowledged as a handmaiden of art, if not admitted to its most exalted ranks.

Having devoted much attention in California to experiments in instantaneous photography, I, in 1872, at the suggestion of the editor of a San Francisco newspaper, obtained a few photographic impressions of a horse during a fast trot.



At this time much controversy prevailed among experienced horsemen as to whether all the feet of a horse while trotting were entirely clear of the ground at the same instant of time. A few experiments made in that year proved a fact which should have been self-evident.

Being much interested with the experiments of Professor Marey, in 1877, I invented a method for the employment of a number of photographic cameras, arranged in a line parallel to a track over which the animal would be caused to move, with the object of obtaining, at regulated intervals of time or distance, several consecutive impressions of him during a single complete stride as he passed along in front of the cameras, and so of more completely investigating the successive attitudes of animals while in motion than could be accomplished by the system of M. Marey.

I explained the plan of my intended experiments to a wealthy res-

ident of San Francisco—Mr. Stanford—who liberally agreed to place the resources of his stock-breeding farm at my disposal, and to reimburse the expenses of my investigations, upon condition of my supplying him, for his private use, with a few copies of the contemplated results. The apparatus used and its arrangement will be better understood by a reference to the accompanying drawings.

Fig. 1. A photographing lens, and camera containing a sensitised plate; and side view of electro-exposor placed in front of camera.

Fig. 2. Back view of electro-exposor. Two shutters P P, each comprising two panels, with an opening O between them, are adjusted to move freely up and down in a frame; they are here arranged ready for an exposure, and are held in position by a latch L and trigger T, all light being excluded from the lens. A slight extra tension of the thread B, Fig. 4, will cause a contact of the metal springs M S, and

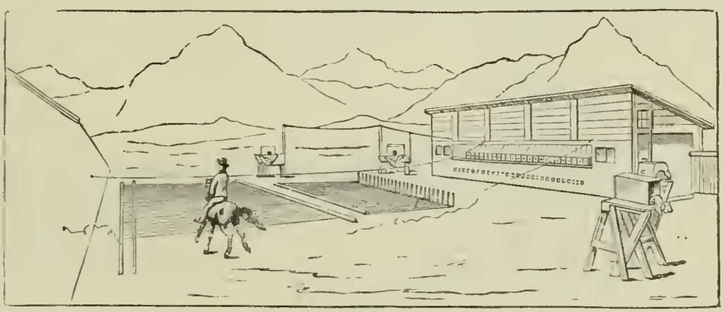


Fig. 5.

complete a circuit of electricity through the wires W W and the electro-magnet M; the consequent attraction causes the armature A to strike the trigger, the latch is released, the shutters are drawn respectively upwards and downwards by means of the rubber springs S S, and light is admitted to the sensitised plate while the openings in the shutters are passing each other in front of the lens.

Fig. 3. Front view of electro-exposor after exposure of the plate.

Fig. 5. General view of studio, operating track, and background. In the studio are arranged 24 photographing cameras; at a distance of 12 inches from the centre of each lens an electro-exposor is securely fixed in front of each camera. Threads 12 inches apart are stretched across the track (only two of which are introduced in the engraving), at a suitable height to strike the breast of the animal experimented with, one end of the thread being fastened to the background, the other to the spring, Fig. 4, which is drawn almost to the point of contact.

The animal in its progress over the track will strike these threads in succeseion, and as each pair of strings is brought into contact, the current of electricity thereby created effects a photographic exposure, as described by Figs. 2 and 4; and each consecutive exposure records the position of the animal at the instant the thread is struck and broken.

For obtaining successive exposures of horses driven in vehicles, one of the wheels is steered in a channel over wires slightly elevated from the ground; the depression of each wire completes an electric circuit, and effects the exposures in the same manner as the threads.

Fig. 6. Operating track, covered with corrugated India rubber, and marked with transverse lines 12 inches apart. Each line is numbered, for the purpose of more readily ascertaining the length of the animal's

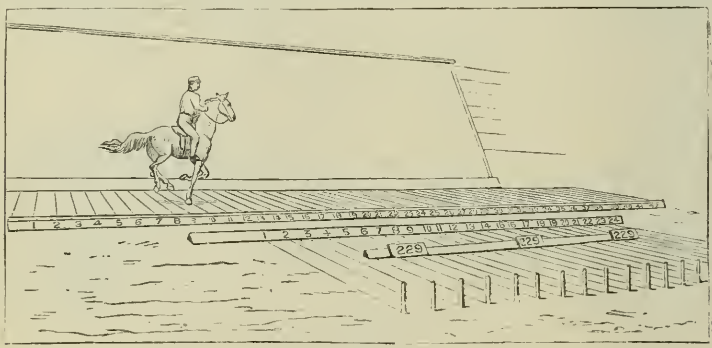


Fig. 6.

stride. On one side of the track, and opposite to the battery of cameras, a white background is erected at a suitable angle.

The camera in which any one negative in a series of exposures is made is designated on that negative by the parallel direction of the vertical stake with the horizontal line extending to the corresponding number immediately opposite. The discriminating number of each series is marked on each negative by the large numbers—229, for example—which are changed for each movement illustrated.

For recording the successive attitudes of animals not under control, an apparatus is used, comprising a cylinder, around which are spirally arranged a number of pins; upon the cylinder being set in motion through gearing connected with a spring or weight, these pins are consecutively brought into contact with a corresponding number of metal springs; a succession of electric currents is thereby created which act

through their respective magnets attached to the electro-exposors at regulated intervals of time. The cylinder is put in motion either by bringing it into gearing with other parts of the apparatus already in motion; or by releasing a break with the hand, or by the action of some object at a distance by means of an electric current.

This apparatus is principally used for illustrating the flight of birds, the motions of small animals, and changes of position without continuous progressive motion, such as occur during wrestling or turning a somersault; when the cameras are directed towards the place where the movements are being executed.

The boxes outside the studio (Fig. 5) contain cameras and electro-exposors for obtaining synchronous exposures of a moving object from different points of view.

The following analyses of some of the movements investigated by the aid of electro-photographic exposures, are rendered more perfectly intelligible by the reproductions of the actual motions projected on the screen through the zoöpraxiscope.

THE WALK.

Selecting the horse for the purposes of illustration, we find that during his slowest progressive movement—the walk—he has always two, and, for a varying period, three feet on the ground at once. With a fast-walking horse the time of support upon three feet is exceedingly brief; while during a very slow walk all four feet are occasionally on the ground at the same instant.

The successive order of what may be termed foot fallings are these. Commencing with the landing of the left hind foot, the next to strike the ground will be the left fore foot, followed in order by the right hind and right fore foot. So far as the camera has revealed, these successive foot fallings during the walk are invariable, and are probably common to all quadrupeds. But the time during which each foot, in its relation to the other feet, remains on the ground, varies greatly with different species of animals, and even with the same animal under different conditions. During an ordinary walk, at the instant preceding the striking of the left hind foot, the body is supported on the right laterals, and the left fore foot is in act of passing to the front of the right fore foot. The two hind feet and the right fore foot immediately divide the weight. The right hind foot is now raised, and the left hind with its diagonal fore foot sustains the body; the left fore next touches the

ground, and for an instant the animal is again on three feet; the right fore foot is immediately raised and again the support is derived from laterals—the left instead of as before the right. One-half of the stride is now completed, and a similar series of alternations, substituting the right feet for the left, completes the other half. These movements will perhaps be more readily understood by a reference to the longitudinal elevation, Fig. 7, No. 1, which illustrates some approximate relative positions of the feet of a rapid walking horse, with a stride of 5 feet 9 inches. The positions of the feet indicated in this, and also in the other strides illustrated in Fig. 7, are copied from photographs, and from them we learn that during an ordinary walk the consecutive supporting feet are—

1. The left hind and left fore—*laterals.*
2. Both hind, and left fore.
3. Right hind and left fore—*diagonals.*
4. Right hind and both fore.
5. Right hind and right fore—*laterals.*
6. Both hind, and right fore.
7. Left hind and right fore—*diagonals.*
8. Left hind and both fore.

Commencing again with the first position; it is thus seen that when a horse during a walk is on two feet, and the other two feet are suspended between the supporting legs, the suspended feet are laterals. On the other hand, when the suspended feet are severally in advance of and behind the supporting legs, they are diagonals.

These invariable rules seem to be neglected or entirely ignored by many of the most eminent animal painters of modern times.

THE TROT.

By some observers the perfect trot is described as an absolutely synchronous movement of the diagonal feet. This simultaneous action may be considered desirable, but it probably never occurs.

Sometimes the fore foot will be raised before the diagonal hind foot, sometimes afterwards; but in either instance, the foot raised first will strike the ground first; repeated experiments with many racing and other trotting horses confirmed this want of simultaneity. Selecting for an example of the trot a horse making a stride of 18 feet in length, we find that at the instant his right fore foot strikes the ground, the left hind foot is a few inches behind the point where it will presently

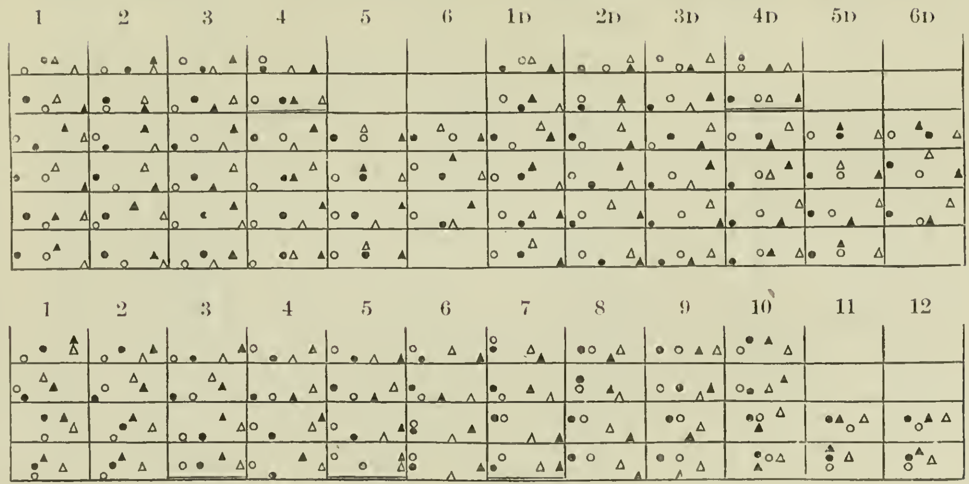
KEY.

	Rt.	*Left.*
Hind Feet.........	●	○
Fore Feet.........	▲	△
Line of Ground	●○	

LONGITUDINAL ELEVATION OF SOME CONSECUTIVE POSITIONS OF THE FEET OF HORSES DURING VARIOUS MOVEMENTS.

Each line illustrates a single complete stride. The comparative distances of the feet from each other, or from the ground, are approximate; not to scale. Direction of movement——>

Action.	Length of Stride. ft.	in.
1. Walking.........	5	9
2. Trotting.........	7	6
3. "	17	6
4. "	18	3
5. Ambling........	10	3
6. Racking.........	12	6
7. Cantering.......	10	3
8. Galloping.......	11	9
9. "	19	9
10. Galloping, a conjectural stride of 22 feet or more.		



Doubtful. Probable. Probable.

strike at about 38 or 40 inches to the rear of the fore foot. When both feet have reached the ground, the right hind leg is stretched back almost to its fullest extent, with the pastern nearly horizontal, while the left fore leg is flexed under the body. As the legs approach a vertical position the pasterns are gradually lowered, and act as springs to break the force of the concussion until they are bent nearly at right angles with the legs.

At this period the left fore foot is raised to its greatest height, and will frequently strike the elbow, while the right hind foot is but little raised from the ground and is about to pass to the front of the left hind.

The pasterns gradually rise as the legs decline backwards until the right fore foot has left the ground and the last propelling force is being exercised by the left hind foot; which accomplished, the animal is in mid air.

The right hind foot continues its onward motion until it is sometimes much in advance of its lateral fore foot, the former, however, being gradually lowered, while the latter is being raised. The right hind and both fore legs are now much flexed, while the left hind is stretched backward to its greatest extent with the bottom of the foot turned upwards, the left fore leg is being thrust forwards and gradually straightened, with the toe raised as the foot approaches the ground; which accomplished, with a substitution of the left limbs for the right we find them in the same relative positions as when we commenced our examination, and one-half of the stride is completed.

With slight and immaterial differences, such as might be caused by irregularities of the ground, these movements are repeated by the other pair of diagonals, and the entire stride is then complete.

Line 4 illustrates a stride of 18 feet 3 inches, and the order of supporting feet are :—

1. The right fore foot.
2. The left hind and right fore feet.
3. The left hind foot.
4. Without support.
5. The left fore foot.
6. The right hind and left fore feet.
7. The right hind foot.
8. Without support.

It appears somewhat remarkable that until the results of M. Marey's

experiments and of those obtained by electro-photography were published, many experienced horsemen were of opinion that during the action of trotting at least one foot of a horse was always in contact with the ground.

If the entire stride of a trotting horse is divided into two portions, representing the comparative distances traversed by the aggregate of the body while the feet are in contact with, and while they are entirely clear of, the ground; the relative measurements will be found to vary very greatly, they being contingent upon length of limb, weight, speed, and other circumstances.

Heavily built horses will sometimes merely drag the feet just above the surface, but, in every instance of a trot, the *weight* of the body is really unsupported twice during each stride (see stride 2, positions 4 and 4D). It sometimes happens that a fast trotter, during the two actions of a stride, will have all his feet clear of the ground for a distance exceeding one-half of the length of the entire stride; this elasticity of movement is however exceptional.

The action of a fast-trotting horse while drawing a vehicle is very different from his action under the saddle; in the latter case, the hind legs are kept thrust back for a longer period, and their final forward movement is much more rapid.

THE AMBLE.

Assuming our observation of this movement to commence when, during a stride of about 10 feet, the left hind foot has just struck the ground slightly to the rear of where the right fore foot is resting; the left fore leg will be well advanced but still flexed, with the toe pointed downwards, and the right hind foot having been the last to leave the ground, will be thrust backwards with the pastern nearly horizontal.

As the right fore foot leaves the ground, the left fore leg is gradually straightened during its thrust forwards; the right hind foot in the meantime is gradually advancing, and the horse is supported on the left hind foot alone.

The left fore foot is now brought to the ground, and the body rests on the left laterals, with the right laterals suspended between them.

As the left fore leg attains a vertical position, its lateral leaves the ground, and the support of the body devolves on the left fore foot alone, the right fore leg being considerably flexed, with the foot in advance of the left fore leg.

The right hind foot now strikes the ground, and one-half of the stride is accomplished; these movements are repeated with a change of the limbs for the remaining portion of the stride, and the horse is again in the position in which we first observed him.

We shall see by reference to stride No. 5 the consecutive supporting feet to be:

1. The left hind foot.
2. The left hind and left fore feet—*laterals.*
3. The left fore foot.
4. The left fore and right hind feet—*diagonals.*
5. The right hind foot.
6. The right hind and right fore feet—*laterals.*
7. The right fore foot.
8. The right fore and left hind feet—*diagonals.*

The right fore foot being raised, the horse is again in the first position.

The amble and the walk are the only regular progressive movements of the horse wherein the body is never without the support of one or more legs, in all others the weight is entirely off the ground for a longer or shorter period.

THE RACK OR PACE.

The rack differs from the trot in the nearly synchronous action of the *laterals* instead of the *diagonals.*

In some countries the rack is naturally adopted by the horse as one of his gaits, but it is probably caused by the effects of training exercised over many generations of his ancestors.

The movements already described are regular in their action, and a stride may be divided into two parts, which are essentially similar to each other.

THE CANTER

and the gallop, however, cannot be so divided, and a complete stride in either of those gaits is a combination of several different movements.

The canter is usually regarded as a slow gallop, probably from the facility with which a change from one gait to the other can be effected; an important difference will, however, be observed.

Assuming a horse after his propulsion through the air, during a stride of 10 feet, to have just landed on his left hind foot, the right hind foot will be on the point of passing to the front of the left. The left fore leg will be thrust forward and nearly straight, while the right

fore leg will be flexed with the foot elevated about 12 inches from the ground, and somewhat behind the vertical of the breast. The left fore foot being brought to the ground, the body is supported by the laterals; the right hind foot is, however, quickly lowered, and performs its share of support. The left hind foot is then raised, and the right hind and left fore legs assume the weight, the former being nearly vertical, and the latter inclined well back, the right fore foot is thrust well forward, and is just about to strike the ground; when it does, three feet again share the support, they being the two fore and the right hind. The left fore foot now leaves the ground, and we again find the support furnished by the laterals, the right instead of, as before, the left.

The right hind foot is raised when the right fore leg becomes vertical; this latter, which now sustains the entire weight, gives the final effort of propulsion, and the body is hurled into the air.

The descent of the left hind foot completes the stride, and the consecutive movements are repeated.

In stride No. 7 we learn that during the canter the support of the body is derived from—

1. The left hind foot.
2. The left hind and left fore feet—*laterals.*
3. Both hind and the left fore feet.
4. The right hind and left fore feet—*diagonals.*
5. The right hind and both fore feet.
6. The right hind and right fore feet—*laterals.*
7. The right fore foot alone, on which he leaves the ground.

THE GALLOP OR RUN.

This movement has in all ages been employed by artists to convey the impression of rapid motion, although, curiously enough, the attitude in which the horse has been almost invariably depicted is one which is impracticable during uniform progressive motion.

When during a rapid gallop, with a stride of 20 feet, a horse after his flight through the air lands on his left hind foot, the right hind will be suspended over it at an elevation of 12 or 15 inches, and several inches to the rear of and above it the sole of the right fore foot will be turned up almost horizontally, the left fore leg is flexed with the foot under the breast at a height of 18 or 20 inches.

The right hind foot strikes the ground some 36 inches in advance of the left hind, each as they land being forward of the centre of gravity.

The body is now thrust forward, and while the right hind pastern is still almost horizontal, the left hind foot leaves the ground. At this time the left fore leg is perfectly straight, the foot, with the toe much higher than the heel, is thrust forward to a point almost vertical with the nose, and at an elevation of about 12 inches the right fore knee is bent at right angles, and the foot suspended under the breast at several inches greater elevation than the left fore foot.

The left fore foot now strikes the ground, 96 inches in advance of the spot which the right hind foot is on the point of leaving, and for a brief space of time the diagonals are upon the ground together. The left fore leg, however, immediately assumes the entire responsibility of the weight, and soon attains a vertical position, with its pastern at right angles to it.

In this position the right hind foot is thrust back to its fullest extent, at an elevation of 12 or 14 inches, with the pastern nearly horizontal. The left hind foot is considerably higher and somewhat more forward; the right fore leg is straight, stretched forward, with the foot about 15 inches from the ground, and almost on a perpendicular line from the nose. The right fore foot strikes the ground 48 inches in advance of the left fore, which, having nearly performed its office, is preparing to leave the ground; the animal will then be supported on the right fore foot alone, which immediately falls well to the rear of the centre of gravity, which is sometimes passed by the left hind foot at a height of about 12 inches; the right hind foot is some distance in the rear, and the left fore foot, at a height of 24 inches, is suspended somewhat in advance of its lateral.

In this position the horse uses the right fore foot for a final act of propulsion, and is carried in mid air for a distance of 60 inches, after which the left hind foot descends, the stride is completed, and the consecutive motions renewed.

The measurements and positions herein given do not pretend to exactness, as they must depend to some extent upon the capability, training, and convenience of the animal; but they may be accepted as representing an average stride of 20 feet with a horse in fair condition for racing.

From this analysis it will be seen, by reference to stride 9, that a horse, during an ordinary gallop, is supported consecutively by:

1. The left hind foot,
2. Both hind feet,

3. The right hind foot,
4. The right hind and left fore feet,
5. The left fore foot,
6. Both fore feet,
7. The right fore foot,

with which he leaves the ground, while the only position in which we find him entirely without support is when all the legs are flexed under his body.

It is highly probable, however, that more exhaustive experiments with long-striding horses in perfect training, will discover there is sometimes an interval of suspension between the lifting of one fore foot and the descent of the other; and also between the lifting of the second hind foot which touches the ground, and the descent of its diagonal fore foot (see imaginary stride 10). Should this latter be the case, it will, from the necessary positions of the other limbs, afford but a very shadowy pretext for the conventional attitude used by artists to represent a gallop. It is extremely doubtful if there can be any interval of suspension between the lifting of one hind foot and the descent of the other, no matter what the length of stride.

Many able scientists have written on the theory of the gallop, but I believe Marey was the first to demonstrate, that in executing this movement, the horse left the ground with a fore foot and landed on a hind foot.

THE LEAP.

There is little essential difference in general characteristics of either of the several movements that have been described, but with a number of experiments made with horses while leaping, no two were found to agree in the manner of execution. The leap of the same horse at the same rate of speed, with the same rider, over the same hurdle, disclosed much variation in the rise, clearance, and descent of the animal. Apart from this, the horses were not thoroughly trained leapers, and the results are perhaps not representative of those that would be obtained from the action of a well-trained hunting horse. A few motions were, however, invariable. While the horse was raising his body to clear the hurdle, one hind foot was always in advance of the other, and exercised its last energy alone.

On the decent, the concussion was always received by one fore foot, supported by the other more or less rapidly, and sometimes as much as 30 inches in advance of where the first one struck, followed by the

hind feet also, with intervals of time and distance between their several falls. It is highly probable future experiments will prove these observations to be invariable in leaping.

It is highly probable that these photographic investigations, which were executed with wet collodion plates with exposures not exceeding in some instances the one five-thousandth part of a second, will dispel many popular illusions as to gait, and that future and more exhaustive experiments, with all the advantages of recent chemical discoveries, will completely unveil to the artist all the visible muscular action of men and animals during their most rapid movements.

The employment of automatic apparatus for the purpose of obtaining a regulated succession of photographic exposures is too recent for its value to be properly understood, or to be generally used for scientific experiment; at a future time, the pathologist, the anatomist, and other explorers for hidden truths will find it indispensable for their complex investigations.

CHARCOAL AS APPLIED TO THE DEPOSITION OF GOLD FROM CHLORINE SOLUTIONS, AND ITS PERFECT SEPARATION FROM COPPER AND OTHER IMPURITIES.

By William Morris Davis.

[A paper read at the Stated Meeting of the Franklin Institute, March 21, 1883.]

As preliminary to the subject, and necessary to a just appreciation of its value in utilizing the refractory ores of gold, it may be remarked that in our country there exist immense amounts of auriferous sulphides, and arsenides, which have not been deemed available on account of their refractory nature, or their low value in gold.

Smelting has only been applied to such ores when they carried a comparatively high value in gold. Kerl teaches that "ores containing combined gold to the amount of $20 per ton cannot be profitably fused with lead, even could they be raised without mining cost."

By chlorination, ores containing combined gold to the amount of $10 per ton can be profitably worked, mining cost included.

This process has not found general application for reasons which will be considered hereafter.

Chlorination of the refractory ores involves three distinct operations, viz.:

1. Roasting, to expel the volatile constituents of the ores, and to oxidize the metallic elements other than gold.

2. Dissolving the gold by means of chlorine, preferably by the Mears process, and by filtration or leaching, separating the auriferous and cuprous solution from the sands.

3. Precipitation of the gold by salt of iron, or sulphuretted hydrogen, or the deposition of the gold, and its complete separation from attendant impurities by percolation through granulated vegetable charcoal.

This last method has been the subject of a United States Patent, and its chemical reactions have been examined by George A. Koenig, and published in the INSTITUTE JOURNAL, May, 1882.

It is herein purposed to consider this new method, in its technical application to enlarged operations in commercially obtaining gold from its solutions, which is attended by phenomena that would not be considered by the experimentalist in the limited operations of the laboratory. Also, to compare the new deposition of gold with the old methods of precipitation.

It has been known to a few antiquarian searchers in chemical records, that amongst the multitude of substances, inorganic and organic, which decompose an acid solution of terchloride of gold, carbon was named by Count Rumford (Sir Benjamin Thompson), as possessing this property. But it was under certain conditions only that he observed it to act; for, he says, "recently ignited charcoal separates gold only in sunshine or a temperature of 109°F."

Further research showed that in the presence of either "sunshine" or a temperature of 109°, gold will be deposited from its solution in the *absence* of carbon.

Thus Kane teaches that "when chlorine water is exposed to the light it is gradually decomposed, chloride of hydrogen being formed, and oxygen set free."

He further teaches that heat has the effect of decomposing such solutions with like results.

Should gold be present, it will be precipitated in proportion as the chlorine is converted into chloride of hydrogen for the reason that gold is insoluble in this acid.

When it was thus shown that the conditions, light and heat, as

named by Rumford, were sufficient for the deposition of gold from its solution, then his supposed discovery was consigned to the limbus of curious and useless chemical observations.

This property of carbon is but casually mentioned by other authors; but it is nowhere taught that carbon is distinguished by a remarkable energy, or as differing from the crowd of organic substances with which it is classed.

Neither is it suggested in any scientific work that the deposition was sufficient to be of commercial value, and, so far as known, no use has ever been made of such knowledge in the commercial separation of gold from its solutions. Nor has it been employed in the metallurgy of gold except as a fuel.

On the contrary, when the attention of chemical experts was first called to the claims of the discoverer, they were discredited by most, and thought by others, deservedly high in authority, to "run counter to well known principles and chemical laws;" even at this time well informed minds are at a loss to account for the remarkable energy of this new agent in reducing gold to a metallic state from its solutions; also the remarkable fact that it is inert towards other metallic and mineral constituents of the solution; thus serving the double purpose of depositing and refining the gold.

Neither are many chemists prepared to admit the following conclusions, derived from experimental observations and investigation during many months of practical operations on a scale, varying from the experiment of ounces in the laboratory, to nearly two thousand tons of ore in the reduction works, in which, over 600,000 gallons of a terchloride solution of gold was subjected to the action of charcoal, and $11,152 in gold retained.

The following formula is offered as explanatory of the reactions attending the deposition of gold from a chlorine solution:

$$2AuCl_3 + 3C + 6HO = 6HCl + 3CO_2 + 2Au \text{ free.}$$

This hypothesis is strengthened by the observed action of chlorine on other substances.

Thus Kane teaches that, "Chlorine has a powerful affinity for hydrogen, and when brought in contact with other bodies, in the presence of water, will decompose the water by combining with the hydrogen forming ClH, and liberating oxygen. Thus he says, substances are frequently oxidized by chlorine to a higher degree than by nitric acid."

Selenious acid (SeO_2) and chlorine, in the presence of water are converted into selenic acid (SeO_3) and ClH, thus:—

$$SeO_2+Cl+HO = SeO_3+ClH.$$

Reasoning from analogy, we may explain the reactions attending the deposition of gold, by substituting carbon for selenious acid; in which case the carbon becomes oxidized at the expense of the water, forming carbonic acid (CO_2), the liberated hydrogen uniting with the chlorine, forming ClH.

That such are the reactions, may be assumed, *a priori*, because all the elements involved are satisfied according to their known affinities, and form definite compounds, leaving the gold free.

It therefore follows, that the deposition of the gold is caused by the conversion of the chlorine (which is a solvent of the metal) into chlorhydric acid, (in which gold is insoluble) and is not occasioned by any particular affinity of the carbon for the gold; and it also follows that copper or other mineral constituents of the solution, will be retained in solution by the ClH, because soluble by it.

That the chlorine is converted into muriatic acid (ClH) was shown by the following experiment.

After a filter containing 80 gallons of coal had passed 8,750 gallons of a strong chlorine solution, there were taken equal portions of the solution, the one from the surface, the other from the lower faucet, after passage through the coal.

In the first sample, the chlorine acted powerfully on the senses; being quite suffocating, in the second no odor was perceptible, even on the application of heat.

By the addition of nitrate of silver, to each sample, and collecting the precipitated chloride of silver, washing and drying with due precautions, the weights of the two agreed; the one determining the sensible chlorine in the original solution, the other the insensible chlorine as existing in the hydrochloric acid formed by the passage over the charcoal.

That the gold disappeared from the solution with the conversion of chlorine, is shown in the following extract from a report on the process by Prof. Endlich, of Washington:

"In order to test the efficacy of the process," he says, "I took, systematically, samples from the receiving tanks, from the collecting tanks, from the pipe which carried the solution to the filter, and from the

stop-cock through which the liquid passed after the solution had been in contact with the charcoal."

"The unvarying result of these repeated tests may be summed up briefly."

"While I never failed to get copious precipitates of gold from the solution in the tanks, and from that taken from the faucet through which it flowed into the carbon filter, I never obtained the slightest gold precipitate from the same liquid after it had passed through the charcoal."

"The experiments I witnessed prove beyond a doubt, the fact, that gold is dissociated by the contact of terchloride solution with carbon and is deposited upon the latter."

"That this deposition is complete is shown by the total absence of gold from the liquid after it had passed through the charcoal filter."

"Briefly restating what has been said at greater length, I would repeat,—the charcoal filter as here used, is entirely sufficient to precipitate from a terchloride solution all the gold contained therein." In laboratory practice, it has been found that proto-sulphate of iron is a most delicate test of the presence of gold in its solution, and is the usual precipitant employed; either this salt or sulphuretted hydrogen amply meets the requirements of the chemist in his researches; for, in the minute proportions therein employed, no account is made of the proportions of the reagents used, and, where the separation of the precipitate from the supernatant fluid is entirely within control, and the time employed is of no especial moment, these reagents suffice.

But, when the ounces employed by the chemist, swell to tons in the hands of the metallurgist, and the solutions grow to unwieldy proportions; when the saline constituents of his solutions vary with the ores operated upon, and when the solution is highly saturated with chlorine (as is the case where it is formed under pressure), or, when the ores are of such low grade, that, to make them available, the costs must be reduced to the lowest; then, the unnoticed factors of the laboratory swell to formidable proportions, and stand, an almost insurmountable bar to the chlorinating process on a business scale. Therefore, chlorination has been confined to quite limited operations, whilst its excellence, as a solvent of the gold, is unquestioned.

It must be admitted that in laboratory experiments, carbon is as inconvenient and impracticable, as the above reagents have proved in operations upon an extended scale.

WHAT IS CLAIMED FOR THE CHARCOAL PROCESS.

1. Commercially depositing gold from its solution by subjecting the same to the action of carbon.

2. Depositing gold from its solution by causing a current of such solution to flow past or through carbon.

3. The process of obtaining gold from its solution by bringing said solution in contact with carbon, and thereby depositing the gold upon it, and of subsequently obtaining the gold from the carbon by incineration, or other equivalent means.

By charcoal the gold is deposited and retained in metallic form on fixed surfaces, as the solution is passing from the mill at the rate of 80 gallons per hour through 80 gallons of coal or, extending over the 24 hours, equal to disposing of the solutions from 6·4 tons of ore for a single filter. By a duplication of the filters, provision may be made for chlorination, equal to the utmost production of a large mine.

By the older and prevalent methods the gold is precipitated in an impalpable powder, in a large volume of fluid of a density of 3° to 5° Beaumé.

By the carbon method, the gold is securely held against waste or loss until the coal is reduced to ash, preparatory to the melting into ingots.

By the old methods, it is to be obtained only by the slow subsidence of the powder to the bottom of the precipitation tanks, to be subsequently collected by decantation or tedious filtrations.

It is proposed to substitute the continuous passage of the solution through coal by a flow regulated with the nicest precision to the requirements of the works, for the intermittent and complex operations incident to precipitation by the old methods, to wit:

1. Accumulation in precipitation tanks.

2. Precipitation, with chance of waste in excess of precipitant.

3. Subsidence, with great loss in time, on account of the great volume of solutions and their density.

4. Decanting, or syphoning, of the supernatant liquid, with probable loss from incomplete subsidence of the gold.

5. Filtration of the fluid contents of tanks, after decanting as far as is safe.

6. Voluminous contents of filters from the foreign substances thrown down with the gold, which embarrass the after-crucible operations.

Louis Blanding, of San Francisco, writes: "I am well, I may say painfully, aware of the defect and shortcoming of the present mode of

precipitation, either by the proto-sulphate of iron, or by the use of sulphuretted hydrogen, for I have for many years faced the difficulties in my own works, and tried in many ways to overcome it."

That you may realize in some degree the difficulties that Mr. Blanding had faced, I quote from Kerl's Metallurgy a description of the operation in the well-known Plattner's Chlorinating Works at Richenstein. This chlorine solution of gold being obtained, the manipulation is as follows:

"The solution first warmed to 25°C., is treated with sulphuretted hydrogen, thus first neutralizing the chlorine, and afterward precipitating the gold."

"The precipitate is allowed to deposit; it is not completely deposited until the following day, when it is filtered.

"The clear liquid from the precipitation vessels is slowly conducted by glass syphons on to paper filters lying on perforated earthen dishes.

"The filtered liquid is led into sumpts to collect any sulphide of gold which may escape from the filters; the deposit in the vessel is washed and poured on the filters.

"320 filters are obtained from 16 days or 24 tons of ore;" (which is only one and a half tons per diem) "they are then dried and carbonized in four large pans, boiled with aqua-regia, washed, and the auric solution filtered into glass cylinders.

"Afterward the filters are again boiled in water, and the gold separated from the solution by sulphate of iron.

"The four precipitates are now collected on two filters, washed first with pure muriatic acid, and afterward with water.

"When eight such filters are collected, they are carbonized and the gold melted with borax and saltpetre."

The above details become truly formidable when carried out in extenso, and the bewildered operator becomes inextricably entangled in the multiplied decantations and filtrations, precipitations, now by one, and again by another agent, solution and re-solutions, washings and carbonizations, which surely accumulate, day by day, in the never-ending details of so complex a method.*

To still further entangle this complicated web, it was found, in our

* A ton of ore furnishes about 300 gallons of solution, including wash water; or a day's work in the Yadkin would require the above operations to be performed on 3,900 *gallons* of liquid. An idea may be thus formed of the labor and tedium attendant on such enlarged drudgery.

works, that the presence of copper interfered with the perfect precipitation of gold by sulphate of iron, even when great excess of the salt was used; the cement copper obtained from the solution after the gold had been precipitated was found to carry 30 cents of gold to the pound.

The ore operated upon yielded 22 pounds of cement copper to the ton; thus the loss in gold was $22 \times 30 = \$6.60$ per ton, which was fully 40 per cent. of the assay value of the ore.

A like interference of copper with the precipitation of gold is recited by Kerl (p. 614), in describing the chlorinating works at Schemnitz, he says:

"The liquid from the precipitated gold is collected and passed over iron, thus yielding some auriferous cement copper, the loss in gold being 18.21 per cent."

The shortcomings and difficulties of the older methods have been very briefly related, that you may realize the satisfaction with which the simple method of percolation through charcoal was welcomed, wherein, to the absolute certainty of securing the gold, was added the perfect separation from copper, and the obtaining the two metals in purity, and at a nominal expense of about 8 cents per ton.

This simple and effective remedy for the shortcomings of precipitation, removed the difficulties of working the most refractory ores of gold on an enlarged scale.

The charcoal filter will apply equally to all the processes of chlorination now known, and will necessarily apply to like processes, the discovery of which await further research and experiment, and which may in turn supercede the Plattner, Kiss, Paxter, Rozner, Mears, or Boynton processes of working gold ores by means of chlorine. It has been found that from one-half to one gallon of charcoal is sufficient for the solution from 1 ton of ore; while the absolute power of the carbon in dissociating gold from chlorine has not been absolutely determined, it has been experimentally proved that two ounces of charcoal will take a coating equal to eighteen and a half dwts., or \$18.50, which carried out shows \$148 to the pound, or \$341,520 to a ton of charcoal.* The gilded grains exhibited on the screen much exceed this amount,

*In practice the operation is not carried to this extreme, because of possible disintegration of the surfaces and the settling of gold in metallic scales to the bottom of the vessel; and again, when a filter is heavily charged, the interest on the contained gold will exceed the cost of a fresh filter.

as they were taken from the surface of the filter, where the proportion of gold to the carbon was greater than the average of the whole contents, which yielded the above result.

It has been found in practice that the gold solution should be subject to the action of the carbon for about one hour, thus a filter containing 80 gallons of carbon may safely pass its own volume of the solution every hour, or the solution from one ton of ore in four hours. At this rate of running (unless the solution is heavily saturated with chlorine) there need be little fear of gold or chlorine escaping from the bottom spigot, but as a safeguard a second filter should be so placed that the upper one may discharge into it; this lower one is to be elevated to the place of the first when it is charged with gold.

In the process under consideration the presence of copper in moderate proportions becomes of advantage.

Whilst the gold to the uttermost particle is retained by the coal, the copper is not affected, and it passes onward in solution as chloride or sulphate, to its appropriate cistern where it is precipitated by scrap-iron, as metallic or cement copper.

Thus two per centum of copper as a by-product, will more than cover the cost of roasting and chlorinating the ore, or 40 pounds copper @ 12½ cents equals $5.00.

If there be silver in the ore, this metal will be converted into an insoluble chloride of silver in the chlorinator; in many ores the gold is alloyed with such proportions of silver that the coating of chloride of silver would protect the enclosed particle of gold from the action of the solvent, but in the revolving cylinder used in the Mears' system of chlorination, the moving sands scour off the curdy chloride of silver, and the chlorine acts with unimpeded energy, to the perfect solution of the gold.

Supposing then, that the ore is a chalcopyrite, carrying gold, silver, and copper sulphide, with ferric bi-sulphide, the elimination of the various elements would be as follows: In the preliminary roasting, the sulphides would be converted to ferric oxide and cuprous sulphate. As such it is subjected in mixture with due proportion of water in a revolving cylinder to the action of chlorine at a pressure equal to two atmospheres for one hour, more or less, according to the coarseness of the contained gold, after which the whole mixture is discharged into a filter arranged with sand and pieces of quartz to act as a leaching tank, from this the fluid contents; carrying the gold and copper, may

be drained and washed away by additional water, to pass through the carbon, where the gold will be intercepted, the copper passing over iron is deposited in metallic form.

Returning now to the washed sands in the leaching vat, we will find the insoluble chloride of silver; by treating these sands with a solution of hypo-sulphide of lime or soda (preferably the former), the silver will be dissolved, and by leaching, the silver solution will be carried to its appropriate tank to be precipitated as a sulphide, by hypo-sulphide of lime. Thus we secure a complete separation and obtain possession of the three metals, the two latter, viz., copper and silver, being by-products of the gold process.

The important question now arises as to the proportion of contained gold that may be obtained by this process.

EXPERIMENTS WITH CHARCOAL IN THE DEPOSITION OF GOLD.

The following details of experiments are given that the scientific reader may see that due precautions were taken to arrive at reliable results. The novelty of the appliances are offered as an apology for the minuteness of detail.

First Experiment.—A glass percolator, 18 inches deep, was filled with granulated pine wood charcoal, of sizes between a No. 16 and No. 40 sieve, a small gum tube and clamp at bottom served to regulate the flow; 3 quarts of coal were employed; and 100 gallons of solution, obtained from ore of the assay value of $15.65 per ton.

The solution represented 750 pounds of the above ore; it was so charged with chlorine that inhalation could not be made at the surface of the coal; temperature of the room, 75°F.; density of the liquid, 3.75° Beaumé. The rate of running was regulated to one gallon per hour.

At the expiration of every hour a sample was taken of the escaping liquid and tested for gold, with sulphate of iron; in each instance it failed to detect gold.

The color of the escaping liquid indicated the presence of copper; remembering that the presence of copper had hitherto impaired the action of sulphate of iron as a precipitant, it remained to be shown that the want of precipitate in the test tubes was a reliable indication of the absence of gold.

As a test, every tenth gallon of the filtrate was subjected to the following treatment:

The copper was precipitated with clean iron wire; the cement copper washed with water on a filter, then dissolved in diluted sulphuric acid and filtered on finest Swedish paper, dried, reduced to an ash, and assayed for gold; the resultant gold found in any single gallon weighed only .01 gr. Now, as one gallon represented $\frac{1}{200}$ of the solution from a charge of 1500 lbs. of ore, the above results shows a loss of but 2 grains, or 8$\frac{2}{3}$ cents per ton of ore.

This result gave assurance that no appreciable gold was passing the filter.

The presence of chlorine was not to be detected in the escaping fluid.

The solution used in the experiment must have carried at least its volume in chlorine, or 13 cubic feet, equal 2·7 lbs. by weight. This disappearance of the chlorine attracted particular notice.

After the passage of the 100 gallons in 100 hour's time, running uninterruptedly, the carbon was washed, carefully incinerated in an open iron dish, and the resultant ash reduced with borax.

The button of gold weighed 139 grains, which being one-half a charge, is equal 278 grains per charge of 1,500 lbs., or

371 grains, at 4¼ cts. equal gold per ton	$15 77
Assay value of ore	15 65
Gold obtained above assay	$0 12

At first blush, it will be thought that more than the assay cannot be obtained. This is an erroneous opinion; a fire assay is but a smelting operation, in which lead particles are employed to wash out the fine atoms of gold diffused in a viscid glassy slag, whilst by solution, as in the case of chlorination, the finer determinations of chemical analyses are reached.

As bearing on this question, it is proper to state that in leaching the chlorinated sands, the washing with water is not continued to a perfect removal of the last traces of gold, as it would require a large volume of water to effect it. A careful supervision is kept by daily or hourly assays of the spent or waste sand, and a point is made that not over 60 cents per ton is allowed to escape. This remains a constant quantity whatsoever may be the value of the one operated upon.

The following results have been obtained on six experimental runs in the Chlorination Works at the Yadkin Mine, near Salisbury, N. C.:

No.	Tons Worked.	Assay per Ton.	Value of Ore.	Gold Mint Returns.	Compared with Assay.
1	17½	$11 90	$208 85	$216 33	+ 45 cts. per ton.
2	30½	11 90	362 95	383 34	+ 66 " "
3	9	25 20	226 80	237 99	+ $1 24 "
4	559	3 61	2,017 99	2,802 00	— 67 " "
5	265	5 04	1,335 60		
6	1,082	7 25	7,842 00	7,513 16	— 80¾ " "
	1,963	$6 11	$11,994 19	$11,152 82	— 43 cts.

COST OF THE PROCESS.

Labor and other charges on a single filter:

14 bushels charcoal, @ 5 cts	70
Grinding and screening, ½ day, @ 60 cts	30
1 boy, regulating flow, 4½ days, @ 25 cts	$1 12½
1 man, burning coal, 1 day, 60 cts	60
Reduction by crucible fluxes, etc	1 50
Equal 80 tons of ore at 5·3 cts. per ton	$4 22½

Briefly to recapitulate the advantages claimed for the carbon process, its peculiar features are:

First.—Great simplicity in all its details, and low cost in appliances, material and labor.

Second.—The complete *deposition* of gold from its solutions.

Third.—Its equal applicability *to all systems of chlorination* as applied to gold ores.

Fourth.—Greatly lessening the chances of loss through ignorance or carelessness of workmen.

Fifth.—The fineness or purity of the gold.

Sixth.—The securing of copper as a by-product at slightly increased cost.

NOTES ON THE PROCESS.

The mining and metallurgy of the precious metals form a lottery, in which the prizes bear an almost infinitesimal proportion to the blanks; in the search for gold this is pre-eminently the case. This arises from various causes:

First.—The minute proportion that gold bears to the ores in which it is held. The average of the ores that are worked carry less than $\frac{1}{45000}$ part gold.

Second.—Only a small proportion of the ores carry gold in an uncombined state (free gold) whilst the refractory pyritous ores offer increased obstruction, costs, waste, and uncertainty, which dishearten the miner and absorb his means.

Nature has so hedged and guarded her treasure-house as almost to justify the legends of the early miners, that kobolds, genii, demons, and elves, stood guard to scare all intruders. Apart from superstitious fears, it stands sure to-day, that nature exacts heavy toll and tribute from those who seek to share her treasure, and places the price so high, that gold will remain a precious metal, however abundantly it may occur.

In the alluvials and gravels of the valleys we meet the debris and sweepings of her treasure-house; in the brooks and rivers, the golden spoils of wasted rocks are offered to tempt us to seek whence they have come, for "Surely," says Job, "there is a vein for the silver, and a place for the gold, when they find it. As for the earth, out of it cometh bread, and under it is turned up as it were fire. The stones of it are the place of sapphires; and it hath dust of gold."

When the sources of rich supply are reached, and with toil and travail we penetrate to the deep deposits that lie stored in the embrace of the suffocating sulphur, or the poisonous arsenic, then unforeseen obstacles interpose, and malign influences oppose steady resistance to the most approved methods and appliances of scientific attainment.

So great have been these obstacles, and so high the cost imposed, that, to this time, man has yielded the point, and allowed the low grade pyritous ores to lie idle in their innumerable lodes.

The prodigal waste, and great cost of the methods in use, in working even the ores of free gold, are voluminously set forth and deplored in the writings of Overman, Raymond, Paul, Kerl, Küstel, Rittenger, and others, who have examined the subject. The recorded result of

their labors will sustain the statement that over thirty per cent. of the gold held in the ore is allowed to escape in the working.

The following figures extracted from official documents, show the percentage of gold lost at some of the most important mines in different parts of the world:

The losses at

The St. Juan del Rey Mine.............................. @	30	per cent.
In the Brazils generally..............................	35	"
In Piedmont	35	"
At Trell..............................	35 to 40	"
In Hungary and the Tyrol..............................	50	"
In Chili..............................	66	"

Let us hope that such may not be the experience of the future, as it can be shown that the most refractory ores, in which at least $\frac{9}{10}$ of the gold of the world is locked, may be reduced at a cost, and with a closeness of saving which will in the end utilize the unmeasured stores of a kind, and grade of ore which has laid idle in ten thousand veins, and thereby add untold treasures to the resources of our country.

THE GREAT ICE AGE IN PENNSYLVANIA.

By Professor H. Carvill Lewis.

[Abstract of a Lecture delivered at the Franklin Institute, January 5, 1883.]

When Agassiz, over forty years ago, after a prolonged study of the Swiss glaciers, announced the conclusion that large portions of the continents of North America and Europe were once covered by an immense glacier, thousands of miles in extent, and several thousand feet in thickness, geologists the world over were startled at what then seemed a most improbable hypothesis. To-day there is hardly a truth in geology more widely accepted or capable of more conclusive proof.

It is here proposed to inquire into the nature of the facts which have led to such a conclusion, and especially to examine those facts in Pennsylvania, recently discovered, which prove the great glacier to have come within sixty miles of our own city.

The great "Northern Drift," as it has long been called by geologists, is a scattered deposit of stones and clay, which, unlike our stratified gravels and clays at Philadelphia, is a confused mixture irregularly dumped over the ground, thick in some places and thin in others, and

apparently unstratified by water. Large boulders are scattered through and upon this deposit, and upon close examination many of these boulders may be seen to be scratched longitudinally. They are of all sizes and shapes, generally rounded, yet often sharp. This deposit, often called *till* or *hardpan,* is not confined to the valleys and lowlands, but may be found covering the whole northern portion of our country, mountains as well as valleys, in an almost continuous mantle. Upon sharp mountain summits, and upon steep slopes, it is represented by the boulders and scratched stones alone; but on the other hand it may be as finely developed upon a high mountain plateau as at the level of the sea. The till has as much depth, and has just as characteristic features on the Alleghany plateau in Potter county, Pennsylvania, for example, at an elevation of over 2,500 feet, as it has at New York City at the level of the sea.

[A photograph was here thrown upon the screen, giving a section of *till* at one of the State quarries at Bangor, Northampton county, Pennsylvania. Large boulders lay imbedded in it at all angles.]

The boulders scattered in great numbers throughout the region covered by the Northern Drift can always be shown to have been transported from a more northern region. The lecturer had found boulders of syenite from the Adirondack mountains, and of granite from Canada of frequent occurrence in Pennsylvania. These are often perched upon mountain summits, and often are lifted from one valley and carried across a mountain range to the south into another valley. Thus the lecturer had found, in the valley immediately south of the Kittatinny mountain, immense boulders of Helderberg fossiliferous limestone which had been derived from outcrops in a valley north of the mountain, the boulders having traveled across the intervening mountain range, 1,500 feet high.

[A photograph was shown of a boulder of conglomerate perched upon the summit of Penobscot Knob, 2,220 feet high, the boulder having been transported from the next mountain on the north and carried across an intervening valley.]

These boulders, as well as the smaller stones imbedded in the till, are frequently scratched as though by some sharp instrument. The scratches on the stones are generally lengthwise, and form a characteristic feature of true till. Nowhere outside of the region covered by the Northern Drift, *except in the vicinity of glaciers,* do similar scratched stones occur.

[Numerous specimens of scratched stones from various parts of the State were exhibited, and a photograph of a large scratched boulder was shown.]

On exposed surfaces of rock, or where the till has been removed by any means, the rocks may be observed to be scratched, grooved, or polished as though by the movement of some solid heavy mass across it.

These grooves or striations are almost always in a southerly direction, and always correspond with the direction in which the accompanying boulders had been transported. The rocks underlying the till are ground off; all decomposed material having been rubbed off and removed by the agent which made the striæ and transported the boulders. No exposures of decomposed rock, such as may be seen anywhere in the vicinity of Philadelphia (at Gray's Ferry, for example), occur in the region of the great Northern Drift. The smooth, rounded surfaces of rock in that region are sometimes known as "*roches moutonnées,*" from their resemblance to the rounded backs of sheep.

[A photograph of striated rock surfaces on Godfrey's ridge, near the Delaware Water Gap, were thrown upon the screen, and specimens exhibited.]

These three phenomena, then, the mantle of till, the transported and scratched boulders, and the smoothed or striated rock surfaces, are characteristic of the region covered by the "Northern Drift," and, with the high-level gravel banks and other phenomena more particularly to be described hereafter, are common throughout large portions of northwestern Europe and northeastern America. It was to satisfactorily explain these phenomenon that Agassiz's theory was proposed.

The early geologists supposed that this great Northern Drift was caused by an immense flood or deluge, the great mass of which swept furiously from the north toward the south, engulfing mountains and valleys alike, and carrying with it great masses of stones and rubbish, which, after the subsidence of the flood, remained as the deposits just described. It was found, however, that no satisfactory cause for such a flood or for such waves of translation could be found; nor could it be shown that water, however heavily laden with detritus, could either scratch the stones it bore, striate and groove rock surfaces, or form unstratified *till.* Nor could any flood transport great boulders across successive mountain ranges to positions often higher than the parent rock.

Another theory was therefore proposed. Great icebergs were supposed to have floated upon an inland sea, and to have both carried the boulders, and to have striated any rocks on which they might have grounded. On the other hand, the absence of any evidences of water

action throughout large regions covered by the till, the absence of any proof that icebergs can produce striæ, the difficulty of explaining the transportation of boulders from valleys to mountain tops, and especially the entire absence of any shore line for such an inland sea, militate strongly against any such theory. The southern edge of the "Northern Drift" beginning at the Atlantic ocean, and extending westward across the Alleghanies in a diagonal line, is anything but a shore line. This theory, however, known as the Iceberg Theory, is still supported by a few geologists, and will therefore be again referred to in our description of the glacial phenomena of Pennsylvania.

The glacial theory of Agassiz, on the other hand, somewhat modified by more recent discoveries, explains the observed facts and is based upon observations of phenomena produced at the present time. At the foot of many of the Swiss glaciers which have retreated from a former position, there may be seen polished and striated rock surfaces, transported and scratched boulders, drift deposits, and many other appearances precisely similar to those exhibited on a larger scale in northern Europe and America.

[The lecturer here described a personal examination of the termini of several Swiss glaciers, and especially of a valley between Meyringen and the Grimsel, where the polished rocks high up on either side showed the valley to be the deserted bed of a glacier.]

There are numerous proofs that the glaciers of Switzerland were formerly of enormously greater size than at present. There are boulders lying on the eastern flank of the Jura mountains which have been carried from Mt. Blanc upon the bosom of a great glacier 150 miles long, 50 miles broad, and 2,000 feet deep. An equally large stream of ice flowed southward from the same mountain far into Italy. A colder climate must have once prevailed to produce such a great extension of the glaciers.

In America also, both in the Rocky Mountains, and in the Sierra Nevada, there were formerly extensive glaciers, where now none, or only traces remain.*

Coming now to the great glacier of central Greenland, which with its extension northward to the Pole makes a true Polar ice-cap, it is most reasonable to suppose that the same refrigeration of climate which caused the local glaciers of Switzerland and of the Rocky and

* Similar evidences of the former greater extension of glaciers are found in many portions of the globe.

Sierra mountains to expand, caused similar great expansion of the Polar ice-cap.

A sea of ice, more than one thousand miles long, and thousands of feet in thickness, never traversed by human feet, now covers the whole interior of Greenland, mountains and valleys alike being buried beneath its mass.

[A description of this great *mer de glace*, as seen by Hayes, Nordenskjöld, and others, was here given.]

Streams of ice, issuing from this Greenland glacier often push far out to sea, where, by the buoyancy of the water, great icebergs are detached. These icebergs are often as much as half a mile in thickness, getting aground in water of that depth.

A sea of ice of even greater thickness covers the Antarctic continent, forming at its edge a wall of ice so high that one could not see over it from the top of a ship's masthead. Croll has estimated the thickness of the Antarctic glacier at its centre to be at least *twelve miles.*

Imagine now, these great polar ice-caps expanded in equal proportion with the local glaciers elsewhere, and the glacial theory is before us.

There is every proof that, ages ago, the climate being colder than now, the great Greenland glacier crept down so as to overspread the northeastern part of America and the northwestern part of Europe. Receiving accessions from such local centres of glaciation as Scandinavia, Scotland, and possibly Labrador, it probably also filled the bed of the Atlantic with ice far south of Greenland, the edge of the glacier reaching from Newfoundland to southern Ireland in a concave line. In its southward advance this great glacier scratched off rock surfaces, striated them in the direction of its motion; and scratched the fragments held in its grasp. Just as the ancient Swiss glacier carried boulders from Mont Blanc to the Juras, so this great continental glacier carried them from Canada across Lake Erie into Pennsylvania. Just as the Greenland glacier now fills the valleys and overtops the mountains, so this larger glacier advanced over mountain and valley alike, in a continuous sheet, to its final halting place, only sixty miles north of Philadelphia.

It is probable that future research will show a similar great icesheet to have advanced northward from the Antarctic continent.

This great northern glacier, reaching in America from Greenland to St. Louis, and from Alaska to New Jersey, was so thick as to overtop

Mt. Washington, dropping transported boulders upon its summit. Even at its very edge, as observed in Pennsylvania, the glacier was at least 800 feet thick. A hundred miles back from its edge, among the Catskills, it was at least 3,100 feet thick, while two hundred miles farther, in northern New England it was 5,000 feet thick. In northern Canada it must have been still thicker.

The thickness of the glacier is known by the height to which transported boulders and striated rock surfaces may be found. Thus in Pennsylvania, the lecturer has found that Pocono Knob, 2,175 feet high, juts into the extreme edge of the glacier, having however no marks of glaciation, and therefore showing the edge of the ice not to have been deep enough to ride over it, while, on the other hand, Penobscot Knob, 2,250 feet high, only eight miles back from the southern edge of the glacier, was overridden by it, exhibiting striations and transported boulders upon its very summit.

It was this glacier which formed the till, which dumped down irregularly the various unstratified deposits so characteristic of the drift-curved region, and which both abraded the rock surfaces and transported and rounded the fragments which it tore off in its passage.

The exact extent of this great glacier is not accurately known in all portions, but is now being studied. In general, it appears that its southern edge extended from Alaska in a southwest direction to the northwest corner of Dakota, whence it passed through the centre of Nebraska and the northeastern corner of Kansas, continuing eastward through the centre of Missouri to the Mississippi river near St. Louis. It then passed along the southern edges of Illinois and Indiana, entering Ohio at Cincinnati, then trending northwest to the Pennsylvania line a few miles north of Beaver. In Pennsylvania, as will presently be stated more in detail, it passed northwest from Beaver county to Warren county, where it entered New York. Making a sharp curve in Cattaraugus county, New York, it again entered Pennsylvania in Potter county, and passed southeast to Belvidere in Northampton county, where it crossed into New Jersey. Passing in a southeast direction across New Jersey to Staten Island, it again entered New York, and traversing the whole length of Long Island finally goes out to sea, appearing on Block Island, Cape Cod, and at a few other detached points. The edge of the glacier probably corresponded with St. George's bank and Sable Island shoal outside of Nova Scotia, and, passing southeast of Newfoundland and south of Greenland,

probably crossed the Northern Atlantic and again passed southward outside of the Irish coast, so as to enter the southwest corner of England. It appears to have crossed England in a westerly direction so as to pass not far from London, and then, crossing the North Sea, to have traversed southern Holland, northern Austria, Saxony, passing near Dresden, until entering Poland, south of Warsaw, it finally curved northeast in Russia, passing east of Moscow, and entering the Arctic Ocean just west of the Ural mountains.

[A map of the world was exhibited, showing the approximate limit of glaciation]

The glacial stream was reinforced by glaciers from the mountains of Scotland and Scandinavia, and these local glaciers have been proved to have remained and to have formed striæ long after the continuous ice-sheet had departed. There are many evidences of a second glaciation of more limited size and of local origin.

That the phenomena of this great drift-covered region are due to the actual presence of a great glacier, rather than to any open sea, bearing icebergs, should be forever settled by the discovery of one crucial fact, the presence of a *terminal moraine*. A true glacier pushes up at its foot a mound of unstratified material, composed of angular, rounded, and striated fragments of rock, which the ice has taken up at various points along its course and carried to its terminus to form a moraine. On the other hand any body of water is bounded by a level shore line composed in great part of water-worn pebbles.

By the discovery in Pennsylvania and in other portions of America of a true terminal moraine, which, as a continuous wall of unstratified and glaciated material, crosses over mountain and valley alike, regardless of topography, everywhere forming the boundary between the glaciated and the non-glaciated region, the glacial theory has recently been remarkably confirmed.

[Professor Lewis here described the investigations in New Jersey, and along Long Island and southern Massachusetts, which first demonstrated the existence of a true terminal moraine, and referred to the discovery of similar moraines in Wisconsin and Minnesota, which marked halting places in the retreat of the glacier. He stated that the "coteaus" of the northwestern prairies have been shown to be parts of such moraines.]

Convinced from personal observations as well as from the considerations just mentioned, that it was possible to trace a terminal moraine across Pennsylvania, the lecturer, having obtained the aid of the Geological Survey of Pennsylvania, and having, through part of the

exploration, the able assistance of Prof. G. F. Wright, had been able to follow and define the southern limit of glaciation for the first time in a continuous line four hundred miles in length across our State, and to find that it is everywhere marked by a remarkable accumulation of glaciated material, which, forming a great terminal moraine, winds across mountains and valleys, across deep ravines and high mountain ridges, from the lowlands of the Delaware to the great Alleghany plateau, is continuous from end to end, and forms a feature of great interest in studies upon the glaciation of this country.

The method employed in discovering the line of the moraine was to zigzag along its course from the glaciated into the non-glaciated region, and *vice versa*, going each time far enough on the one side to be fully satisfied of the absence of glaciation, and on the other to find undoubted traces of its action.

The distinction between the glaciated portion of Pennsylvania and that region south of glacial action is very marked. Although the general topography of the two regions is alike, the varied superficial features due to glacial agencies, the far traveled and scratched boulders, the smoothed and striated rock exposures, the unstratified deposit of impure clay, which, filled irregularly with both round and sharp stones, has been called *till*, the long *hummocky* ridges of stratified sand and gravel known as *Kames*, and especially the numerous glacier-scratched fragments and pebbles, all these deposits are in strong contrast with those south of the glacial action, where all the gravels are stratified and the pebbles water-worn, where the rocks are never polished or striated, but, on the other hand, often decomposed to a great depth and where, except near the sea coast, wide stretches of the more elevated regions are perfectly free from all drift.

The line separating the glaciated from the non-glaciated region is especially defined by a remarkable accumulation of unstratified drift material and boulders, which, heaped up into irregular hills and hollows over a strip of ground nearly a mile in width, forms a continuous line of drift hills more or less marked, extending completely across the State. These hills vary in height from a few feet up to 100 to 200 feet, and while in some places marked merely by an unusual collection of large transported boulders, at other places rise as immense accumulations to form a noteworthy feature of the landscape. When typically developed, this accumulation is characterized by peculiar contours of its own. A series of *hummocks* or low conical hills, alternate

with short straight ridges, and enclose shallow basin-shaped depressions, which like inverted *hummocks* in shape, are known as *kettle holes.* Large boulders are scattered over the surface, and the unstratified *till* which composes the deposit is filled with glacier scratched boulders and fragments of all sizes and shapes. The average width of the moraine is about one mile.

The two facts which are of especial importance in relation to this line of drift hills are, (1.) That, as shown by the absence of stratification, by the angularity and the striated surfaces of its enclosed stones, and by its topograpical position, it has rarely been subjected to the action of water ; (2.) That, as proved by numerous glacial striæ and by transported boulders, its course is always at right angles to the direction of glacial movement.

These facts, with others about to be given in detail, led the speaker to regard this accumulation as a true *terminal moraine*, marking the southern extension of the great ice-sheet of northeastern America. Like the moraine at the foot of the Rhone glacier, which, as recently observed by Chamberlin, forms diminutive hummocks and kettle holes, and has on a small scale the same characters and topography as the great moraines of Wisconsin, this great Pennsylvania moraine appears to have been pushed out at the foot of the great glacier of the ice age.

The general course of this moraine across our State is as follows (see accompanying map): Appearing first in Northampton county, a mile below Belvidere, at latitude 40° 49′, it appears through the stratified drift as low gravel hills, which, winding up over the slate hills to the west, are soon developed into an accumulation of typical till, holding kettle holes and filled with boulders. Winding in a great curve first westward and then northward, it reaches the base of the Kittatinny mountain three miles east of the Wind Gap.

Ascending to the top of the Kittatinny mountain, 1600 feet high, the moraine crosses over it, being well shown upon the very summit, and entering Monroe county, crosses the great valley between the Kittatinny and the Pocono, enclosing in its course several moraine lakes. Having crossed this valley, and reached the base of the Pocono escarpment, it swings sharply back and around Pocono Knob, immediately afterwards to ascend the steep face of the mountain to the wide plateau on top, 2100 feet above the sea. Crossing this in a majestic curve, heaped up in an immense accumulation, it goes first north and afterwards west, until it reaches the Carbon county line.

Crossing the centre of Kidder township, Carbon county, it reaches the gorge of the Lehigh river, some ten miles north of Mauch Chunk. It crosses the gorge at Hickory run, and, without swerving from its general northwestern course, ascends mountain range after mountain range in Luzerne county, descends to the valley of the east branch of the Susquehanna, and crosses the river at Beach Haven, here forming immense heaps of drift, afterwards to be washed down the river into terraces.

Then, in Columbia county, following along the base of Huntington or Knob mountain for awhile, it finally ascends it, and crossing over the summit at a height of 1500 feet above the Susquehanna just below, descends the north slope of the mountain to the broad undulating valley to the north. Taking a northerly course, it follows up on the east bank of Fishing creek to the north or Alleghany mountain. The summit of the Alleghanies in Sullivan county is covered with glacial striæ, and contains boulders and other marks of glaciation. The moraine entering Lycoming county, passes westward along the base of the mountain, crossing in its course the Muncy and Loyalsock creeks, and finally, near the village of Loyalsock, turns at right angles and ascends the mountain.

Having reached the summit of the Alleghenies, over 2000 feet above the sea, it crosses the picturesque canon of Lycoming creek, and passing west through a wild, wooded region nearly as far as Pine creek, it begins a nearly straight northwestward course, through the southwest corner of Tioga county, and the northwest part of Potter. In the high ground of Potter county, the moraine crosses a great continental watershed, from which the waters flow into the Gulf of Mexico, Lake Ontario, and Chesapeake bay. The moraine is here finely shown at an elevation of 2580 feet, being higher than elsewhere in the United States.

The line of the moraine now enters the State of New York, in the southwest corner of Allegheny county. Passing still northwest and entering Cattaraugus county, it twice crosses the winding course of the Allegheny river, east and west of Olean, then, trending to a point five miles north of Salamanca, in latitude 42° 15′, it forms a remarkable apex, from whence to the Ohio line its course is southwest. Turning at right angles to its former course, the moraine passes southwest through the southeast corner of Chautauqua county, and keeping approximately parallel to the course of the Allegheny river, re-enters

Pennsylvania, in Pine Grove township, Warren county. It crosses the Conewango river seven miles north of Warren, forming immense accumulations in the valley of the river.

Then trending west in Warren county, still at a general elevation of nearly 2000 feet above the sea, it crosses one gorge after another, and forms a line separating, not only the glaciated from the non-glaciated region, but also the cultivated from the uncultivated and densely wooded region.

In Crawford county, the line appears in the southeast corner, and crosses Oil creek between four and five miles northwest of Titusville.

In Venango county it skirts the northwest and west boundary of the county, crossing French creek four miles west of Franklin.

It crosses the three northwest townships of Butler county, and the southeast corner of Lawrence. The Beaver river is crossed by the moraine eight miles south of New Castle.

The moraine traverses the extreme northwest corner of Beaver county, and, in the middle of Darlington township, thirteen miles north of the Ohio river, and at a latitude of 40° 50′, crosses the Ohio State line.

The moraine thus leaves Pennsylvania at precisely the latitude at which it entered the State, and if a straight line were drawn across the State between these two points, the line of the moraine would form with it a right angled triangle, whose apex was 100 miles distant perpendicularly from its base. The total length of the moraine, as here shown, is about 400 miles. The moraine crosses the Delaware at an elevation of 250 feet, the Allegheny at an elevation of 1425 feet, and the Beaver at an elevation of 800 feet above the sea, or 225 feet above Lake Erie. Upon the high lands it rises higher by 1000 feet or more.

Coming now to the details of the moraine, it will be impossible in the brief space of a lecture to mention more than a very few of the many interesting phenomena noticed all along its course. The details in full will be found in forthcoming Report Z. of the Geological Survey of the State. The beautiful photographs thrown upon the screen were made by Mr. E. H. Harden, of the Geological Survey, and are the first ever taken or exhibited of the Great Terminal Moraine in any part of the world.

[Photographs were exhibited of the moraine, near Bangor, Northampton county; details of the same; moraine near Saylorsburg, Monroe county; "kettle-holes" in the same; moraine on summit of Pocono mountain; moraine forming dam on Fishing creek, Columbia county, etc.]

In *Northampton* county, the moraine is very finely developed west of Bangor, where it forms a series of "hummocky" hills, which, 100 to 200 feet in height, and covered with transported and striated boulders, rise abruptly out of a clayey plain to the west. Glacial striæ upon exposed surfaces near Bangor point southwest, or towards the moraine. After following the moraine to the base of the Kittatinny mountain, it became of great interest to know whether a great lobe of ice descended from New Jersey along the lower side of the mountain, or whether a tongue projected through the Delaware Water Gap, or whether the glacier even so close to its southern limit, came bodily over the top of the mountain, unchecked by it, and unchanged in its course. The last, the most improbable of these hypotheses, and certainly the least expected by the speaker, proved to be undoubtedly the true one. The speaker had been able to show that the moraine crossed mountain near Offset Knob, that large boulders, derived from lower elevations several miles northward, lie perched all along the summit, 1400 feet above the sea, and that, as shown by the numerous striæ on the northern slope of the mountain, running *up-hill*, the glacier moved diagonally up and across the mountain, uninfluenced in any way by the presence of the Water Gap, and finally came to an end in the valley south of the mountain, as marked out by the terminal moraine. Huge boulders of fossiliferous limestone, sometimes 30 feet long, were torn by the ice from their parent strata in Monroe county, on the north side of the mountain, lifted up a thousand feet, carried across the mountain, and dropped finally in the slate valley of Northampton county. The lecturer had found one of these limestone boulders upon the very summit of the mountain, where the jagged sandstone rocks had combed it out of the ice during its passage across. The journeys of these boulders were short, but that of a well-rounded boulder of Adirondack syenite, which the lecturer had found in the same county, was about 200 miles.

In *Monroe* county, the course of the moraine as it winds from the top of the Kittatinny mountain down to Cherry Valley and then up again on to the Pocono, is a complete vindication of the glacial hypothesis. It is in no sense a water level, nor could it have been formed by floating ice. No other cause than that of a great glacier could form a continuous accumulation of glaciated material, which contains no evidences of water action and which follows such a course. The fact discovered that no tongues of ice were protruded either through the

Delaware Water Gap or down the broad valley between the Pocono and Kittatinny mountains, indicates the immense size of the glacier. Although more than 1000 feet lower than the mountains and 12 miles in width, the valley last mentioned deflected the southern boundary of the ice but a few miles.

[There are no striæ indicating passage of ice through the Water Gap, the supposed striæ being due to water action.]

Again, neither on the mountains nor in the valley does the moraine rest against any defined barrier as would be the case were it a shore-line.

The moraine is wonderfully shown upon the summit of Pocono mountain, over 2000 feet above the sea, where a great ridge of moraine hills twelve miles long, one mile wide, and 100 feet or more high, composed of unstratified till, and bearing numerous boulders of Adirondack gneisses and granites, rises out of the level, sandy plain of the Pocono plateau and sweeps around from Pocono Knob into Carbon county. Known locally as "Long Ridge," its origin has never before been suspected. It encloses remarkable little "moraine lakes" without inlet or outlet, and is heaped up into just such conical hills as may be seen in the moraine in Southern Massachusetts. Nothing can more clearly show the continuity and uniformity of action of the great glacier than the identity of its moraine accumulations at such remote points.

[The lecturer here described some of the *striæ* of Monroe county, exhibiting photographs. One photograph represents *cross striæ* seen south of Stroudsburg. A second movement of the glacier down hill, after it had become smaller, had crossed the striæ made by a more general movement of the ice. He said that the direction of ice movement could often be told from the cuneiform shape of the striæ.]

The "*Kames*" of Cherry Valley, fine examples of which appear south of Stroudsburg, are interesting relics of sub-glacial water action. They are composed of stratified water-worn gravel, having often an anticlinal structure, and, as a series of conical hills and reticulated ridges, enclosing "kettle holes," form conspicuous objects in the centre of the valley. They appear to have been formed by sub-glacial rivers, which flowing from the moraine *backwards*, under or at the edge of the ice, emptied into the Delaware Valley. A study of the great sub-glacial drainage, of which kames are the most prominent relics, throws much light upon certain high-level stratified gravels whose origin has been ascribed to great changes of elevation.

[Photographs of *Kames* in Cherry Valley were exhibited. The lecturer then described the *terraces* near Stroudsburg, and referred to the Indian name of that region, Minisink, meaning "the waters have gone," as an indication of the legendary memory of the flood following the retreat of the glacier. He exhibited a photograph of a glacial groove which he had discovered on the Kittatinny mountain near the Water Gap, which, six feet wide and seventy feet long, had been gouged out by some great rock imbedded in the moving glacier.]

Immense as was the power of the slowly moving glacier, it had but slight effect upon the topography of the country. It is a mistake to suppose that glaciers can level down mountains or scoop out cañons. The glacier has merely "sandpapered" the surface of the rocks. The glacier passed bodily across the sharp edge of the Kittatiny mountain without having any appreciable effect upon it, the glaciated part of the ridge being as high and as sharp as that part south of the moraine.

In *Carbon* county, the moraine passes across the wild wooded region in the most northern township of the county, enclosing several moraine lakes in its course and crossing the Lehigh near Hickory run. These moraine lakes are kettle-holes holding water, while other lakes, such as Long Pond on the Pocono plateau, are due to the damming up of their outlets by the moraine. An abundance of lakes is characteristic of a glaciated region, being generally due to the obstruction of streams by the unequal distribution of the till.

The point where the moraine crosses the Lehigh may be distinctly seen by any one traveling upon either the Lehigh Valley Railroad or the Lehigh and Susquehanna Railroad, the contrast between the glaciated and the non-glaciated regions being sharply defined. South of the moraine, the rocks bordering the picturesque gorge of the Lehigh are bare or covered with frost-broken fragments, while the products of aerial erosion known as "Pulpit Rocks" may be seen. The gorges formed by tributary streams are rocky and free from gravel. On the other hand, in the glaciated portion of the valley, a covering of gravel and rounded boulders appears on either side, and the drift has filled up the gorges occupied by tributary streams, often transforming them into shallow valleys, while terraces and ridges of gravel appear in the river valley itself. Just above White Haven, glacial striæ upon the rocks may be seen from the car windows.

The general movement of the ice throughout this region, as shown by the striæ upon the summit of Penobscot Knob, 2200 feet high, is south 10° west. This is precisely at right angles to the course of the

moraine. The latter traverses the southern part of *Luzerne* county in a direction north of west, crossing in its course numerous mountain chains, by each of which it is locally deflected northward.

[The lecturer here described some of the glacial phenomena of Luzerne county. He stated that at the point where the terminal moraine crosses Buck mountain, in a line diagonally across the mountain, the moraine is so sharply defined that he was able to stand with one foot upon the glaciated and the other upon the non-glaciated region. He described the fine kames between Scranton and Pittston, on the Lackawanna river, and showed that they were nearly parallel to the glacial striæ.

He then gave some details of the course of the moraine as traced through *Columbia* county. He stated that it was interesting to find that in *front* of a mountain chain, such as Huntington mountain or the Alleghany mountain, the moraine was poorly developed, as though the mountain had *combed out* the drift from the ice. Speaking of certain gravel deposits south of the moraine, due to floating ice, he said that the best test of a glaciated region is the striation of its pebbles.

He described an instructive portion of the moraine, where, 3½ miles northwest of Berwick, it seems to abut against a high slate hill, which furnishes, therefore, a *section* of the end of the glacier. It shows that the extreme edge of the ice was about 400 feet thick, and that while the moraine and the scratched pebbles were carried along at the base of the ice, sharp fragments of sandstone were carried on top.

The interesting course of the moraine along the eastern bank of Fishing creek was described, where the glacier stopped abruptly on the downward slope of a hill, stopping simply because its inertia became exhausted. A photograph of the moraine where it crossed the creek, forming a great dam, was exhibited, and it was shown that the moraine was often steeper at the back than at its front edge—a fact analogous with the features of modern Swiss moraines.

The evidences of glaciation upon the Alleghany mountain in Sullivan county were given, the striæ pointing south 9° west, and the moraine was followed along the base of the mountain to a point in *Lycoming* county near Loyalsock, where it climbed up to the great Alleghany plateau, and then, keeping at a high elevation, passed through Tioga and Potter counties into New York.]

That this great region of high elevation (over 2500 feet) had a decided influence upon the general course of the moraine is inferred from the local influence already shown by the lecturer to have been exerted by single mountain chains, and it is probable that as the lowlands along the Atlantic allowed the ice to flow as far south as Belvidere, so this great mountain region, acting like a wedge, caused the moraine to swing northward into New York; and so, too, the depressions of Lake Erie and the Mississippi Valley produced another and more

extended southward flow, a portion of which traversed the western part of our State.

[Professor Lewis here described the remarkable apex made by the moraine north of Salamanca, N. Y. He showed that it was probable that the Allegheny river flowed under a tongue of the glacier, 10 miles broad and 2 miles long, through a sub-glacial channel at the time of its greatest extension near Olean. He described a great natural dam across the valley of Great Valley creek, near Peth, where the moraine stretches across the valley from side to side, and he spoke of the contrast between the numerous drainage valleys which drained the waters of the melting ice into the Alleghany river, and those valleys which took their rise south of the moraine and were free from all drift.

After giving some details of the western lobe of the ice sheet in Pennsylvania, he spoke of some curious deposits of glaciated material which occurred in a narrow strip of ground immediately in front of the moraine, and which he had named the *fringe.* These deposits consisted of boulders of Canadian granite, and other rocks, which he found perched upon the summits of hills, sometimes as far as five miles in front of the moraine, though never farther. This glacial "fringe," confined to the western part of the State, was found to increase in width from two miles in Warren county, to five miles on the Ohio line, and was at first a puzzling phenomenon. The hypothesis proposed was that, like breakers on the seashore, the top of the ice overreached the lowest strata by the width of the "fringe," and that while the moraine marked the halting place of the bottom of the ice, by which it was formed, the far-transported boulders were carried on more rapidly in the top strata of the ice, and were dropped outside of the moraine to form the "fringe." Other facts observed in the western part of the State were given, and specimens of Canadian boulders were exhibited. It was stated that the striæ in the western part of the State all pointed southeast, being at right angles to those in the eastern part of the State, but like them, pointing always towards the moraine.]

Having thus reviewed briefly some of the more important glacial phenomena of our State, it remains to inquire into the probable *cause* of the great glacier, into the origin of the cold that allowed the polar ice-cap to creep down as far as the great terminal moraine, and finally into the probable *age* of the glacial epoch.

Among the various causes assigned, by different writers, for the glacial epoch, the following may be enumerated:

1. Changes in the obliquity of the ecliptic.
2. Changes in the position of the earth's axis of rotation.
3. The precession of the equinoxes, combined with a greater eccentricity of the earth's orbit.
4. Variations in the amount of heat given off by the sun.
5. Differences in the temperature of portions of space passed through by the earth.

6. Differences in the distribution of land and water, and differences in the elevation of certain portions of the earth.

7. Differences in the flow of oceanic currents, and a change of direction of the gulf stream.

8. Changes in the earth's atmosphere, in its capacity for allowing the radiation of heat, in its power of absorbing moisture, in its density and height, in its temperature, and in the height to which clouds can rise in polar regions.

Still other causes, such as the gradual cooling of the earth from a state of incandescence, have been assigned.

The most probable of these theories are the third and sixth of the above list.

[Professor Lewis here explained the astronomical changes which would cause the winters to be longer than the summers, thus preventing the melting of the accumulating snow. He showed that owing to the elliptical form of the earth's orbit we are about 3,000,000 miles nearer the sun in the winter than in the summer of the northern hemisphere, but that 10,500 years ago this condition of things was reversed, and that we were nearer the sun in summer. He showed also that whereas the sun is now nearly in the centre of the earth's orbit, about 100,000 years ago the eccentricity of our orbit was much greater, the pole then being 8,000,000 miles nearer the sun in winter than in summer. He thought, however, that terrestrial causes were much more potent in causing the glacial epoch than any astronomical changes. There is reason for believing that in glacial times, the land in Labrador and Greenland was elevated at least 600 feet higher than at present, and that at the same time the warm oceanic currents were withdrawn. The glacier grew in the neighborhood of the Atlantic and Hudson's Bay, where moisture was abundant, and did not reach into the dry interiors of either America or Asia. He explained Croll's molecular theory of the motion of the ice, and suggested the possibility of a glacier flowing towards an origin of heat without the aid of gravity.]

Finally, it becomes of interest to inquire into the length of the glacial epoch, and to estimate, if possible, the time that has elapsed since the glacier retreated from Pennsylvania to its present home in Greenland. Astronomical data teach that the cold period began 240,000 years ago. Now, just as every year the greatest cold of our winter does not occur at the time of the shortest day, but fully six weeks later, so it is evident that the greatest cold of the glacial epoch did not occur till many thousands of years after the date mentioned. Again, the great eccentricity of our orbit ended 80,000 years ago, but just as our winter snows remain long into the spring, so the great glacier remained long after its immediate cause had been withdrawn. The larger the mass of ice, the longer it would take to melt. There are

data which lead us to believe that the glacier did not finally withdraw from the United States until as recently as 10,000 to 15,000 years ago. We are here on delicate ground, for geological time is relative rather than absolute, and it is not safe to fix dates. Even in history, all dates back of the time of Abraham are most uncertain.

Special interest, however, attaches to speculations regarding the time of the close of the glacial epoch, since it has been shown to be closely connected with the antiquity of the human race. Stone implements, made by man, have been discovered on both continents in gravels deposited at the close of the glacial epoch. They have been found under conditions that leave no doubt that man, in a rude state, with habits resembling those of the Esquimaux, lived at the time when the river valleys were flooded with water from the melting glacier. That man existed before the glacial epoch, has been inferred from certain facts, but not satisfactorily proven. The speaker has made careful search in glacial deposits all along the line of the moraine for traces of man, without success; while, on the other hand, in the post-glacial gravels of the Delaware, as will be shown in the next lecture, human implements have been found in abundance by Dr. Abbott.

So important, therefore, does the time of the final melting of the glacier become, that we are tempted to inquire still further, even at the risk of too greatly prolonging this lecture, and to gather what facts we can to bear on our subject.

It is a question which geological data alone are insufficient to solve. The only clew, and that a most unsatisfactory one, is afforded by calculations based upon the amount of erosion. This, like all geological considerations, is relative rather than absolute, yet several calculations have been made, which, based either upon the rate of erosion of river channels, or the rate of accumulation of sediment, have attempted to fix the date of the close of the glacial epoch.

When a student of surface geology, who has lived south of glacial action, examines for the first time the true glacial drift and sees the kame-like ridges and bowl-shaped depressions maintaining regular outlines and steep slopes, he cannot but be struck with the comparatively recent look of these deposits. He cannot but believe that if the great periods of time have elapsed since their depositions, which some geologists maintain, the gravel ridges would be rounded down and the kettle-holes filled up by the erosive action of frost, rain and wind. Recent investigations in glacial geology are bringing forward many

THE GREAT TERMINAL MORAINE ACROSS PENNSYLVANIA. by H. CARVILL LEWIS.
NOTE. The Glaciated area is shaded.

evidences that the final disappearance of the glacier in eastern America was not far remote.

Prof. Chamberlin's statement, that "no sensible denudation has taken place in Wisconsin since the glacial times in either drift bearing or driftless areas;" Mr. Upham's remark, when speaking of the lakes which dot the surface of Minnesota, that "the lapse of time since the ice age has been insufficient for rains and streams to fill these basins with sediment, or to cut outlets low enough to drain them; though in many instances we can see such changes slowly going forward;" and Dr. Dawson's observation that "In Canada, the character of the river-courses cut through the glacial beds, and their very unformed and imperfect excavation would lead to the belief that only a few thousands of years have elapsed since the glacial beds were laid down;" these, with similar observations by the lecturer, all agree with conclusions drawn from the good preservation of shells and bones in terrace deposits, and the fact that in zoology since the glacial age no geological changes even leading to the production of varieties have occurred, in bringing the close of the glacial age into our own epoch.

Prof. Wright finds from a study of a glacial "kettle hole" in Massachusetts, that the accumulation of peaty matter in it, whether caused by growth of vegetation or by winds and rains, is equal to a level deposit of eight feet in thickness. At the rate of one inch in a century, which is probably less than the true rate, this would place the close of the glacial epoch at less than ten thousand years ago.

A still more recent estimate has been made by Dr. Andrews, who, from calculations based upon the erosive action of the great lakes, concludes that the total lake deposits made since the glacial epoch, were formed within seventy-five hundred years.

Another source of calculation is the recession of the falls of a river since glacial times. The most notable calculation of this kind is that made upon the recession of the Falls of Niagara. A gorge seven miles in length has been cut from Lewiston to the present falls. Beds containing recent shells and mastodon teeth occur in the banks above the gorge, at the whirlpool, three miles below the falls, and also on Goat Island above the falls, indicating that the waters of Lake Erie once extended up over the gorge and present falls, and that since that period a large portion of the gorge had been excavated. At the whirlpool is an ancient pre-glacial channel, which, having been filled

with drift in glacial times, forced the river to cut a new channel through the rock since that period.

There are here, therefore, data for calculating the close of the glacial epoch. If the whole gorge has been cut out since that epoch, at the rate of one foot per year, thirty-five thousand years would be required. It has been, however, more than once suggested that a portion of the gorge is pre-glacial. Prof. Dana supposed about one mile of it to be pre-glacial, but Mr. Belt, after a personal investigation, concludes that the gorge above the whirlpool was excavated nearly up to the present position of the falls in pre-glacial times. After giving the evidences upon which he founds his opinion, he says: "If the conclusion at which I have arrived is correct, that the gorge from the whirlpool to the falls is pre-glacial, and that the present river has only cut through the softer beds between Queenstown and the whirlpool, and above the latter point merely cleared out the pre-glacial gorge in the harder rocks, twenty thousand years or even less is amply sufficient for the work done, and the occurrence of the glacial epoch, as so measured, will be brought within the shorter period that, from other considerations I have argued, has elapsed since it was at its height."

A calculation of a similar kind has been made by Prof. Winchell, upon the recession of the falls of St. Anthony, since the last glacial epoch. These falls, in the Mississippi river, were discovered in 1680, and a continuous record of their recession may be found since then. A narrow gorge, formed by their recession, extends from the falls to Fort Snelling, eight miles south. Below this point the valley widens, and shows evidence of having been excavated in pre-glacial times. From the falls to Fort Snelling, however, the drift, which lies above the rocky walls of the gorge, has been cut through so as to form a bluff on either side; a fact, showing the post-glacial age of this gorge. An ancient channel of the river, now filled with glacial drift, is described and the evidence seems decisive that, since the glacial epoch, the river, having been forced out of its old channel, has cut out a new one eight miles long, through the rock. Unlike the rocks at Niagara, those at the falls of St. Anthony are horizontal and of unvarying composition, and any conclusions made here will be of much greater accuracy. Prof. Winchell gives three separate measurements, which result in the following terms of years required for the total recession, viz.:—12,103 years; 6,276 years; and 8,202 years. He holds that

an average of these rates—8,860 years—represents the time which has elapsed since the maximum cold of the last glacial epoch.

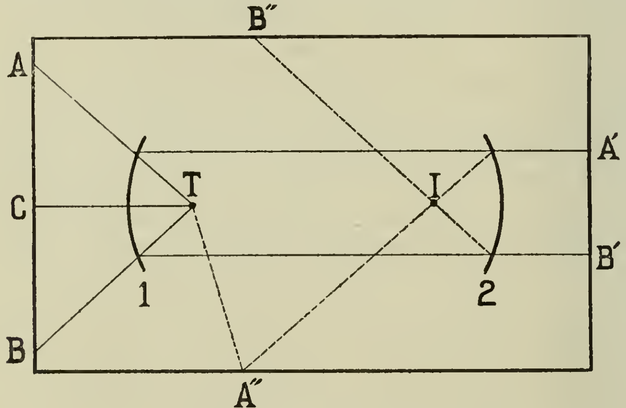
Thus we find, that if any reliance is to be placed upon such calculations, the time of the melting of the glacier need not be longer back than from 10,000 to 15,000 years ago. The conditions at that time will be treated of in our next lecture. It may be that as investigations are carried further, they will result not so much in proving man of very great antiquity, as in showing how much more recent than usually supposed was the final disappearance of the glacier. Here, however, we are entering a field where many sciences meet and where each must help the other.

APPARENT RADIATION AND REFLECTION OF COLD.

By Prof. Charles. F. Himes, Ph.D., Carlisle, Pa.

The explanation usually given in text-books of the depression of a thermometer in the focus of a concave mirror by a piece of ice placed in the focus of an opposite similar mirror, based on the inequality of exchange of heat between the bodies, seems so consistent with the theory of exchanges, that it is generally accepted with little reflection, and it is difficult to understand how any misconception in regard to it can arise. Occasionally, however, upon fuller examination, questions present themselves that seem quite perplexing. In a recent communication to a prominent popular scientific periodical the statement of a leading encyclopœdia, in regard to the experiment, is criticised as an "obvious error," and the theory of exchanges is called in question, and, in a subsequent communication by another, the difficulty is not very satisfactorily disposed of. It may be substantially stated as follows:—All bodies radiate heat, colder bodies only less than warmer ones, at a rate dependent for each one solely upon its temperature. Thus the thermometer before the ice is introduced radiates heat at a rate dependent on its temperature. The introduction of the ice into the focus of the other mirror in no manner affects this radiation, and consequent loss of heat, by the thermometer, whilst the ice on the contrary, not being absolutely cold, radiates heat, which by reflection from the mirrors reaches the thermometer, and should, and does in a measure, replace the heat lost by its radiation; and yet in spite of this increment of heat the thermometer does not rise, but falls. The apparent radiation of cold in this

case, and in all others, if carefully examined, will be found to be only a case of substitution of rays of feebler intensity for some of those *previously received* by a body, whilst the rate of radiation from the body, and consequent loss of heat, remains unchanged; and by considering the part the surrounding objects—the inclosure—play in all such cases the apparent inconsistencies will vanish. When a thermometer has acquired a constant temperature in a room it is receiving and emittting equal amounts of heat. The sum of the radiations from the various points of the inclosure equals the radiation from the thermometer. If a body colder than the inclosure is now introduced near it, as a piece of ice, it will obstruct rays from numerous points, the nearer it is to the thermometer the greater the number, and will send its own feebler rays to the thermometer, whilst it will not in any manner affect the radiation from and consequent loss of heat by the



thermometer, and the thermometer will fall because the amount of heat received will be less than that previously received, whilst that emitted remains the same. The introduction of a mirror, as 1, in the figure so that the thermometer shall be in its focus, does not essentially modify the conditions. The mirror cuts off, it is true, rays from many points of the inclosure, but the thermometer remains unaffected, because rays are substituted from other parts of the inclosure, by reflection from the mirror, which did not reach the thermometer before. Thus rays from *A*, *C*, *B*, are cut off from the thermometer *T*, but are replaced by rays parallel to the axis of the mirror from *A′* and *B′*, whilst that from *C* is replaced by one from *T* normal to the mirror. By the introduction of a second mirror, 2, parallel to the first, these

rays from A' and B' will also be obstructed, but will be replaced by others, as from A'' and B'', that pass through the focus I of the second mirror, and are consequently reflected parallel to its axis, and therefore, by the first mirror to the thermometer. If a body is placed in the focus, I of the second mirror, it will obstruct the rays from A'' and B'' as well, and will send its own rays along the same lines to the mirror, which will reach the thermometer, by reflection from the first mirror; if the body is colder than the inclosure, as a piece of ice, these rays will be feebler than those from A'' and B'', whilst the thermometer will radiate at the same rate as before, and the thermometer will fall; if it is hotter than the inclosure, for similar reasons, the thermometer will rise. The preceding discussion of an ideal case omits, of course, many factors involved in the actual experiment, as absorption by, and radiation, from the imperfect reflectors, direct radiation from the body to the thermometer, etc. Allusion to these, whilst unnecessary, would have complicated the discussion and would have tended to withdraw attention from the feature of the phenomenon to which it was intended specially to direct it.

A SINGULAR CASE OF CORROSION OF STEEL.

By Prof. Chas. E. Munroe, U. S. N. A.

Through the kindness of Chief Engineer Farmer, my attention has recently been called to the appearance of two cold chisels found in the U. S. S. *Triana* in 1874, and which have since been preserved in the Department of Steam Engineering at the Naval Academy. These chisels were taken from the channelway leading from the jet condenser, and they were located between the foot valve and the air pump. Both chisels were of steel throughout, as was proved by tempering the head. For use, of course, only the points had been tempered. During the time of exposure to the action of the salt water in the channelway the chisels were deeply corroded, but the corrosion was confined entirely to the soft metal, the tempered points not being attacked in the least. The corrosion was deepest at the line of contact between the tempered points and the untempered metal of the haft. The line of immersion, on tempering, is as distinctly marked as if drawn with a shading pen. Since meeting with these chisels, I have

heard of a similar case of corrosion, although the object has been lost. It was a hammer which had been taken from the boiler of a merchant steamer, the tempered faces of which were intact while the soft metal was corroded.

Remembering the heated discussion going on in metallurgical circles on the question "What is Steel?" I shall not attempt to decide whether the change which takes place in the tempering of steel is a chemical or a physical one, but it is evident that this change produces a body which is not so readily acted upon by salt water as untempered steel is. It is also probable that when the untempered and tempered steels are brought in contact in the presence of salt water we have an electrochemical couple, and that this hastens the destruction of the untempered metal. I beg to suggest that this observation may have a practical bearing upon the construction of steel ships.

Helmholtz's Theory of Double Electric Layers.—G. Lippmann examines Helmholtz's hypothesis, that the difference of potential between two conductors which are in contact implies the presence of a double electric layer, situated at the surface of contact. The hypothesis leads to a parabolic relation of the second degree, between the capillary tension and the difference of potential, and admits of experiments which lead to quantitative results tending to confirm the truth of the hypothesis. From these experiments he infers that the mean value of a molecular interval is $\frac{1}{35000000}$ of a millimetre. This value is $\frac{6}{7}$ as great as that which was found by Sir William Thompson by an entirely different method.—*Comptes Rendus*, Oct. 16, 1882. C.

Solar Induction.—M. Quet examines the hypothesis that the inductive forces, which the sun develops in bodies by his rotation, vary, other things being equal, in the inverse ratio of the squares of the distances. For any body moving in a circular orbit about the sun, in the plane of its equator, the two forces of induction which are applied to it and which are due, the one to its velocity of revolution and the other to the sun's rotation, have a ratio equal to that of the time employed by the sun to make a complete rotation upon its axis and by the revolving body to complete its revolution. He gives a table of the comparative induction upon the several planets and of the immense variations of electric energy in comets, when approaching and receding from perihelion.—*Comptes Rendus*, Oct. 16, 1882. C.

Production of Organic Acids by Electrolysis.—Bartoli and Papasogli have lately published some curious electrolytic experiments. They employed as electrodes, in a water voltametre, carbons of coke or of wood purified by chlorine, and noticed that the carbons were attacked, so that the liquid became black; with 1200 Daniells acting for a month without interruption, the liquid acquires an acid reaction and yields the compounds of the benzo-carbonic series, mellitic acid, with its derivatives, and a black substance composed of carbon, hydrogen and oxygen, slightly soluble in water and insoluble in alcohol and chloroform. The same results were obtained in various acid or alkaline solutions. If graphite is employed the liquid does not become colored. —*Lum. Electrique.* C.

Influence of Electricity on Vegetation.—M. Macagno has experimented near Palermo upon the influence of atmospheric electricity on the growth of grape vines. Sixteen feet were submitted to the action of an electric current, by means of a copper wire inserted by a platinum point in the extremity of a fruit-bearing branch, while another wire connected the branch at its origin with the soil. The experiment lasted from April to September. The wood of the branches which were experimented upon contained less potash and other mineral matters than the rest of the vine, but the leaves had an excess of potash under the form of bitartrate; the grapes collected from the electrized branches furnished more must, contained more glucose and were less acid.—*Les Mondes.* C.

Analysis of Animal and Vegetable Fibres.—Rough analyses of textile fibres may be made by burning or by boiling in nitric acid. Animal fibres emit peculiar odor, burn with difficulty, and leave a spongy coal; vegetables fibres burn readily, without appreciable residue and almost without smell. In nitric acid silk becomes bright yellow; wool deep yellow; cotton, hemp and linen remain white. A better way is first carefully to wash the stuff, then rinse it thoroughly and dry it. The sample is then placed in a solution of caustic soda and boiled until the animal matter is dissolved. The residue is poured upon a filter, which retains the vegetable fibres; these are washed, to remove all traces of soda, dried and weighed. If the sample originally weighed 5 gr. and the residue weighs 1.5 gr., the animal fibre must have been 3.5 gr.; in other words, the proportion of wool in the material is 70 per cent.—*Bull. de la Soc. d'Encour*, Aug., 1882. C.

Air-proof Cement.—C. Pascher finds that the only substance which is really efficacious for rendering cements unalterable by the air, is a cold solution of one part of sulphate of iron in three parts of water. The cement articles are left in the solution for twenty-four hours; at the end of this time they take a greenish-black tint, due to the hydrated protoxide of iron. The absorbed solution is decomposed in the interior of the cement; the weight of the cement is increased ten per cent.; all the pores of the mass are thus stopped by the hydrate, and as this combination is not attacked by the air, the cement itself becomes unalterable. Cement facings may be whitewashed with several coats of the solution. After drying the cement may be covered with a wash of ochre, or by a solution of ten per cent. of sulphate of alumina in three parts of water. For a greenish-white coating, the surface may be first washed with a solution of chrome alum and then with soap-suds. Either of these coats may be painted in distemper. When oil colors are used upon naked cement they easily scale off. This inconvenience may be avoided by washing the cement with soap-suds, letting it dry, and rubbing with a brush or linen cloth until the surface shines. —*Chron. Industr.*, No. 41. C.

Tornadoes in the United States.—M. Faye acknowledges the receipt, from General Hazen, of Finley's report on the character of six hundred tornadoes, which have been observed in the United States during the present century. He finds evidence in the report of a large opening in each tornado, in which all the living force due to the inequalities of velocity in the upper current is stored. The direction of 372 tornadoes was definitely determined; 310 came from the S. W., 38 from the N. W., 18 from S. S. E., 5 from W. N. W., 3 from N. N. E. Hence it appears that the tornadoes are formed almost exclusively in the dangerous semi-circle of a cyclone, and almost always a little in advance. The simultaneous groups of tornadoes are found, almost without exception, in the afternoon, from 3 to 7 o'clock. The hours from 4 to 5 o'clock are those in which the atmosphere, heated to its maximum at about 2 o'clock and consequently expanded, descends by cooling. The upper currents which control the cyclones are due to slight differences of level, like the ocean and river currents. M. Faye recommends that houses should be built facing one of the four cardinal points and provided with barometers, which all the inmates should learn to read and understand.—*Comptes Rendus*, Oct. 16, 1882. C.

Influence of Temperature on Metalloid Spectra.—Kirchhoff and Bunsen have shown that the temperature of the flame in which a metal is reduced to vapor has no influence upon the position of the brilliant lines in its spectrum. When the temperature is raised, fine new lines usually appear, but those which were shown at lower temperatures still remain. This is not the case, however, with metalloids. Plücker has shown that they give two different spectra, according as the tubes are heated by the ordinary spark or by that of the Leyden jar. Van Monckhoven has found, by numerous experiments, that it is possible to produce the spectra which have usually been attributed to high temperature at very low temperatures, and *vice versâ*. By a critical experiment he was able to produce the two spectra superposed, so that, according to Plücker's hypothesis, the gas should have had at the same instant two different temperatures, which is of course inadmissible. He attributes the change of spectra to a special vibratory state of the molecules, directly dependent upon the nature of the electricity employed.—*Comptes Rendus*, xcv, 520. C.

Nature and Propagation of Electricity.—A. Ledieu communicates a note on the rational conception of the nature and propagation of electricity, deduced from the consideration of the potential energy of æthereal matter associated with ponderable matter, and from the mode of production and transmission of the work, which comes from variations of that energy. He calls special attention to the fact that the numerous values which have been obtained, experimentally, for the coefficient of transformation, oscillate about the numerical value of the velocity of light. This circumstance shows an intimate relation between electricity and the cosmic æther. It is, moreover, accompanied by many others, such as the double refraction of glass and of certain liquids under the influence of the induction spark; the rotation of the light reflected upon a magnet; the action of light upon the electric conductibility of selenium in the photophone. M. Ledieu considers that the hydrodynamic imitations of electric and magnetic effects, by Bjerknes and Decharme, furnish only false analogies, and he thinks it indispensable, while abandoning the notion of electric flow, neither to assume the idea of waves nor of molecular shocks, but simply to consider the action of central forces.—*Comptes Rendus*, Oct. 16, 1882. C.

Signals to Prevent Collisions at Sea.—Captain Littrow, of the Austrian marine, proposes to add to the green lantern upon the right and red upon the left of the vessel, two similar lanterns upon the prow. In this way, when two ships are in a straight line the lights of the stern are hidden by those of the prow; if, then, one of the boats turns to the right, it displays the red lights of its left, and the other ship, turning in the opposite direction, will show the green lights of its right. If one of the ships should see suddenly before it two red or green lights its path would be perpendicular to that of the vessel which it is approaching, and it should stop immediately.—*Chron. Industr.*, No. 41. C.

Origin of Storms.—Spring attributes the appearance of a thunder-storm to a sudden condensation of atmospheric vapor, not into a mist but into hail. The source of the electricity is the rupture of the adherence of the air to the particles of hail; the electric influence then carries the electricity, which was accumulated upon each particle of ice, to the particles which form the limit of the frozen region. Abbé Moigno fears that this theory rests on a vicious circle, for the condensation of water, under the form of hail or of rain, can only take place by reason of an electric discharge. All the secret of thunder-storms is to be found in a *nimbus* encountered by a very cold, very dry and highly electrified *cirrus*.—*Les Mondes*, iii, 254. C.

The Sense of Direction in Animals.—The remarkable faculty which cats, dogs, pigeons, and other animals possess, of returning in a straight line to a point of departure, has awakened much curiosity on the part of naturalists. Some refer it to instinct, some to intelligence similar to that of man, some to an internal mechanism which makes the animals simple automata; but none of these attempted explanations do anything towards solving the mystery. Wallace supposed that when an animal is carried to a great distance in a basket, its fright makes it very attentive to the different odors which it encounters upon the way, and that the return of these odors, in inverse order, furnishes the needful guide. Toussenel supposes that birds recognize the north as the cold quarter, the south as the warm, the east (in France) as the dry, and the west as the moist. Viguier, in the *Revue Philosophique*, publishes an original memoir upon the sense of orientation and its organs, in which he attributes the faculty to a perception of magnetic currents.—*Chron. Industr.*, Nov. 2, 1882. C.

New Method of Cutting Glass.—M. Fahdt, of Dresden, uses metallic wires heated to redness by electricity, for cutting glass. When the circuit is closed the wire communicates its heat to the glass, which cracks under the influence of a sudden cooling by contact with a moist body. To remove the inequalities of the section, it is exposed to a flame by turning so that the flame will reach all the points. The object is then placed in an oven, in order to prevent the parts which have been heated by the flame from cooling too suddenly. —*Chron. Industr.*, No. 37. C.

Combustion of Carbon at High Temperatures.—It has generally been believed that high temperatures favor the formation of carbonic acid, while low temperatures favor the formation of carbonic oxide. Prof. Ledebur has burnt definite weights of charcoal at different temperatures with definite volumes of air, measuring, in each instance, the quantities of carbonic acid and of carbonic oxide which were given off. On gradually increasing the temperature from 350° to 1100° (662° to 2012°F.) he observed an increasing proportion of carbonic oxide and a decreasing proportion of carbonic acid. At the highest temperature the gas was almost exclusively carbonic oxide. These results are contrary to the theories which have been generally admitted by metallurgists.—*Chron. Industr.*, No. 40. C.

Limits of Electrolysis.—The labors of Joule and Favre have established some definite relations between electro-motive forces and the heats of combination in metals. The application of these laws to the electrolysis of salts is often very obscure, especially where secondary actions are produced and where it is desired to know the exact sum of all the energies which really concur in the electrolytic phenomenon. Berthelot has accordingly studied nascent electrolysis, before the composition of the saline solutions has been complicated by the progress of decomposition. He finds that the limit of the efficacious electro-motive forces is uncertain when there is polarization: in order to allow for the polarization it would be necessary to know the real nature of the compounds and their proper heat of formation. Independently of this complication, he finds in electrolysis, as in thermo-chemistry and in a multitude of natural phenomena, the mechanical principle of least action.—*Ann. de Chim. et de Phys.*, xxvii, No. 89. C.

Watch Glasses.—The watch glasses which are now used are moulded by a process which was invented, in 1791, by Pierre Royer, a Parisian manufacturer. C. Launier gives an interesting description of one of the large factories and of the different processes of manufacture. Two and a half million watches are now made annually, and more than seventy millions have been sold within the last half century. On account of the large consumption, and the large stocks which every watchmaker requires to keep on hand, the annual product of watch glasses cannot be less than a hundred million.—*La Nature,* Oct. 21, 1882. C.

Irrigation in Algiers.—M. Jus has addressed to the French Société d'Encouragement some notices, charts, and pictures referring to the Algerian oases and the animals which live in the artesian wells. He gives interesting statistics respecting the settlements, the dwellings, the palm and fruit trees, the value of the annual products, the increase and results of irrigation, which have raised the annual production from 1,654,000 francs in 1856 to 5,549,018 francs in 1880. The improvements have saved from ruin many oases which were upon the point of being relinquished, and have extended the blessing of peace over a region which was always at war before the French occupation; moreover, they have largely increased the material well-being of the native tribes.—*Bull. de la Soc. d'Encour.,* Aug., 1882. C.

Injurious Modes of Lubrication.—Schoudorf recounts the examination of the large cylinder in a Woolf engine, employed in the mines of Sarrebruck. On opening the cylinder there was found upon the piston a brown, wax-like mass, weighing more than 150 kilogrammes (330·7 lbs.). It contained 60 per cent. oxide of iron, 26·77 per cent. of organic matters soluble in alcohol, 5·7 per cent. of insoluble organic matter, the residue being composed of water with a little silicic acid. The cylinder had been in use for about a year, during which time 192 kilogrammes of suet had been employed for lubrication. The decomposition of the suet by steam into glycerine and fatty acids led to the formation of a soap of protoxide of iron. The oxidation of the iron, which is limited chiefly to the interior surface of the cylinder, gradually produces an enlargement of the diameter. The evil may be obviated by using as a lubricant mineral oil of good quality, which boils only at a very high temperature.—*Chron. Industr.,* Oct. 12, 1882. C.

A New Genesis.—On a beautiful summer's night, August 22, 1794, Jerome and Lefrançais de Lalande noticed a star in Aquarius, which they estimated of the $7\frac{1}{2}$ magnitude. Six years later they thought it of the 8 magnitude. In appearance it resembles a star, which is not exactly in the focus of the telescope. Herschel had observed it in September, 1782, and recorded it as an admirable planetary nebula, very brilliant, small, and elliptical. Lord Rosse and Lassell perceived that it was surrounded by a ring, which gives it somewhat the appearance of Saturn. The spectroscopic observations of Huggins indicate that it is a gaseous mass, in which nitrogen and hydrogen predominate. Most of the other planetary and annular nebulæ give similar results. In 1871 and 1872, Brunnow, the Irish astronomer royal, measured its parallax, and concluded that its distance is more than 404,000 times as great as that of the sun, and its diameter is probably greater than that of the entire solar system. This would make its volume more than 338,896,800,000,000,000 times as great as that of the earth. We have thus before our eyes a new system, which is probably undergoing the process of condensation, through which our sun and its attendant planets passed hundreds of millions of years ago.—*L'Astronomie*, Oct., 1882. C.

Franklin Institute.

Hall of the Institute, March 21, 1883.

The stated meeting of the Institute was held at the usual hour, with the President, Wm. P. Tatham, in the chair.

Present, 220 members and 30 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the meeting held March 14, 1883, 16 persons had been elected to membership.

The Secretary, from the Committee on Science and the Arts, reported, by instruction, that the Committee had recommended the award of the Scott Legacy Medal and Premium to Hugo Bilgram, of Philadelphia, for his improvement in Gearing for Metal Planers, and to Thomas Shaw, of Philadelphia, for his improvement in Friction-Buffers. He

also reported that the above recommendations had been duly advertised for three months, and that no objections had been offered thereto.

The recommendations were thereupon taken up separately and approved without dissenting vote, and the Secretary was instructed to notify the Committee on Minor Trusts of the Board of City Trusts, of the action of the Institute.

The Special Committee on the Prevention of Fires in Theatres reported progress, and was continued.

Mr. William B. Le Van then read a paper entitled "Sixty Miles an Hour on Present Road-beds." The speaker claimed that this average speed could readily be maintained upon existing road-beds by introducing a suitable cut-off valve upon the locomotives. He exhibited a series of diagrams taken from well-known locomotives, showing their relative economy. Among them were diagrams from a locomotive in use on the Central Pacific Railway, and provided with a cut-off valve, which showed a very close approximation to the theoretical diagram (about 90 per cent.), and showing a mean effective pressure in the cylinder of 92 pounds to the square inch; whereas, in the diagrams taken from our best fast passenger locomotives, the average mean pressure in the cylinder only averaged 44 pounds, and the efficiency of the engines averaged but 60 per cent. The speaker also advocated the use of higher pressures (up to 210 pounds) as a measure of economy. The paper has been referred for publication.

Mr. William Morris Davis followed with a paper on "Charcoal as applied to the Deposition of Gold from Chlorine Solutions, and its perfect Separation from Copper and other Impurities." The paper is published in this issue of the JOURNAL.

Mr. Otto C. Wolf, by request, described a large sized model representing the valve mechanism of William F. Goodwin's High Speed Engine. The peculiarity of this engine consists in having four distinct valves—two steam and two exhaust valves—circular in form, similar to those in use on the Corliss engine, but differing in respect to location, two being placed in the front head and two in the back head of the cylinder, thereby reducing the clearance space to a minimum. The clearance is further reduced by providing projections or lugs on both faces of the piston, which fill the inlet and outlet ports when the piston is at the extreme ends of its stroke, thereby reducing the clearance in practice to 1·8 per cent. of piston displacement.

Mr. Wolf here took exception to Mr. Le Van's statement that the

placing of an independent cut-off valve upon locomotive engines would overcome the wire-drawing that nearly all the indicator cards showed at high speeds. Mr. Wolf made the point that the steam passages were not properly proportioned, and even if the cut-off gear would allow entire opening of the ports, the passages themselves would wire-draw the entering steam. An instance was cited where the steam would require to have a velocity of over 20,000 feet per minute to follow the piston at the high speed of the engine. If the question of port area were properly considered and proportioned to the maximum speed desired of the engine, future locomotive indicator cards would not be subject to the criticism that they are at present. By such an arrangement of valves as in Mr. Goodwin's model, this could be done without increasing the clearance space. Mr. Rufus Hill had demonstrated upon the engines of the Camden and Atlantic Railroad the importance of this question.

Mr. Le Van asked why the exhaust valves were not placed on a level with the bottom of the cylinder instead of being located some 4 inches above the bottom, thereby incurring the risk in locomotive practice of damming the water in the cylinder instead of giving free access of the same by gravity to the exhaust port, as is ordinarily done in the Corliss, Wheelock, Buckeye, and other engines.

Mr. Goodwin replied that were he to place the exhaust valves as suggested by Mr. Le Van, he would be unable to have the projections or lugs on the piston to assist in reducing the clearance as above stated.

Mr. Robert Grimshaw, by request, exhibited on the screen several views, showing the action of the valve movement of the Shaw Locomotive, explaining the questions of the lead and lap of both steam and exhaust sides of the valve.

The Secretary's report included a description of the following mechanical novelties:

The Hall Type Writer, an illustrated description of which will appear in the JOURNAL; Spicer's Fire Escape, consisting of two series of passage or escape-ways, one being within the building, and the other exterior thereto. The inner passage-ways are enclosed by masonry, and the outer ones by metallic sheathing. Each floor of the building is provided with one of these inner passage-ways, which is furnished with an inwardly opening door, kept closed by a spring or weight. The inner passage-ways communicate with the outer ones, and the latter are provided with ladders or staircases, by means of

which communication is had from one inner passage-way to another, until the ground floor is reached; Matthews' Steam Spring Packing for piston-rods and slide valve stems, particularly the latter. A steam tight bonnet is added to the usual stuffing-box, in place of the "gland" or follower, and metallic packing-rings fitting the rod snugly, slide steam-tight in the truly cylindrical bore of the stuffing-box. This device is reported to be in use by many of the New England Railroad Companies; Gandy's Cam Lever Saw-set, designed for setting the teeth of band or circular saws, by bending them. The teeth are placed between a stationery die and a moveable lever, brought down by a lever with a cam end and retired by a spring. The amount of set is regulated by thumb nuts on the shaft, in the bow of which the cam is pivoted. A number of saws for key-holes, circles, etc., were shown in behalf of the makers, Henry Disston & Sons. In these the teeth were given a backward rake so that the saw will cut on the pull instead of on the push, as with the customary make of saw. With this modification in the direction of the teeth, the thinnest blade can be used without danger of breaking or buckling.

Under new business, Dr. Persifor Frazer offered the following resolution:

Resolved, That the President be authorized and requested to appoint as early as practicable, a committee to examine the several forms of apparatus used for projections upon the screen, of illustrations of all kinds, for lectures, etc.; that the said committee be requested to invite the co-operation of those interested in the manufacture and use of these instruments, to the end that they may be induced to offer their instruments for competitive tests in comparison with others; that the committee have the permission to make use of the lecture-room of the INSTITUTE for their purpose on any evening when it is not engaged; and that they be requested to prepare a report embodying the results of their investigations, together with such recommendations respecting the construction and use of such instruments as they may deem proper to make.

The resolution was carried.

The President appointed Dr. Persifor Frazer, Dr. Charles M. Cresson, A. E. Outerbridge, Jr., Coleman Sellers, and Dr. J. Gibbons Hunt to serve on the committee.

Adjourned.

WILLIAM H. WAHL, *Secretary*.

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ON THE TEMPERATURE OF THE SUN.*

By HUGO BILGRAM.

Several years ago an article came to my notice stating the estimates of the temperature of the sun, by different authors. These figures varied between about 4,000 and 4,000,000 degrees, Centigrade. It is not difficult to conclude that such a difference cannot be attributed to errors of observation, and that some of the theories on which those estimates were based must have been erroneous.

Having some inclination for such studies I tried to find a method myself for making an estimate, and during these studies a series of very interesting points suggested themselves to my mind that were new to me, and may be so in part to others. The following is a brief statement of these studies, and of the results arrived at.

We receive heat from the sun by radiation exclusively, and the laws of radiant heat were the only resort for the intended investigations.

It is well known that if an object of one temperature is surrounded by walls of another temperature, an exchange of heat will take place by radiation, until the temperatures of both the inclosed object and the

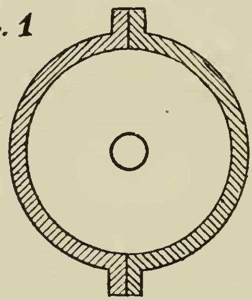
* The above paper was read at the stated meeting of the Institute, held May 17, 1876. As it anticipates some conclusions reached in recent investigations, it has been thought desirable to publish it.—H. B.

surrounding walls are equalized. [Theoretically the temperatures will never be equalized, just as the branch of a hyperbola never meets its asymptote, but after a longer or shorter time the difference will become practically imperceptible.]

The following ideal experiments are supposed to be made in a vacuum to exclude the effect of conduction and convection of heat.

If a globular body (see Fig. 1) is inclosed centrally by two hemispherical walls of different, but permanent temperatures, a continual exchange of heat will take place. It will receive heat from the warmer side, and give off heat to the colder side. Supposing the central body be a perfect conductor of heat, its ultimate temperature will depend on two conditions; on the temperature of each of the hemispheres, and on the condition of their radiating surfaces.

Fig. 1



In text-books the radiation of heat is stated to be in direct proportion to the temperature and to a coefficient expressing the radiating quality of the surface.

If the radiating quality is equal for both hemispheres the central body will accordingly assume a temperature which is the arithmetical mean of those of the two hemispheres. When, however, the radiating surfaces are different, the temperature of the central body will incline towards that of the better radiator.

This law can be generalized. If different portions of the surrounding sphere are of different temperatures and of different radiating qualities, the ultimate temperature of the central body may be expressed by the formula

$$T = \frac{\Sigma\, t \,.\, a \,.\, c}{\Sigma\, a \,.\, c},$$

t being the temperatures, a the areas and c the coefficients of radiation

of the different portions of the spheres, and if the radiating condition of the whole surface is uniform, and besides if the entire surface is taken as a unit, the formula is reduced to $T = \Sigma t . a$.

Now suppose we remove a small portion of the surrounding sphere, say $\frac{1}{100}$, and substitute another piece, the temperature of which is 100° higher, the effect upon the central object will be to raise its temperature $\frac{1}{100}$ of $100° = 1°$, or in general, $T' = T + a\tau$. [1]

On this proposition I based my experiment, assuming the firmament to be the surrounding sphere, and the sun the heated portion thereof; but instead of using a globular central body, I used a flat piece of blackened sheet brass, under which I placed a thermometer, guarding the whole combination on the lower side as well as I could from loss of heat by conduction. I thereby gained two decided advantages. The whole receiving surface being exposed to the same conditions, no internal exchange of heat was occasioned after the terminal condition of heat was established, and further, the radiating surface being reduced to one-fourth, for the same bundle of solar rays received, the heating effect was increased, and the error of observation accordingly reduced.

The described instrument was exposed to the sun on the roof of a house, and after the thermometer came to a rest it indicated 50° C. Then the sun was screened off by a screen just sufficiently large to shade the whole instrument, and the thermometer came down to 28°. Several repetitions of the experiment yielded similar results, the difference always being about 22°.*

The diameter of the sun being about 0° 32′, the area covered by him is $\frac{1}{184650}$ of the entire firmament, but the effect of the sun having been quadrupled, due to the shape of the instrument, the proportion to be considered is $\frac{1}{46163}$.† The temperature of the sun is therefore $46162 \times 22 = 1{\cdot}015{\cdot}586°$, provided our premises are correct, and also provided the radiating quality of the sun is equal to that of the rest of the firmament. The ray-absorbing quality of any surface being equivalent to the radiating quality; and the universe being a perfect absorber of rays, and the atmosphere a poor reflector, the sphere surrounding our experiment can be regarded as a very good radiator, and

* In a subsequent discussion, upon the statement of Professor Snyder that this difference was found $= 29°$ by other observers, I admitted that the result of my observation may have been impaired by moisture in the atmosphere, on the day of the experiment.

† Professor Snyder doubted the propriety of this conclusion in the subsequent discussion.

unless the sun's surface is an equally good radiator, the above estimate is too small. Moreover, the absorption of part of the solar rays by the atmosphere, will doubtless affect this result somewhat, but to avoid complications this factor will here be totally disregarded.*

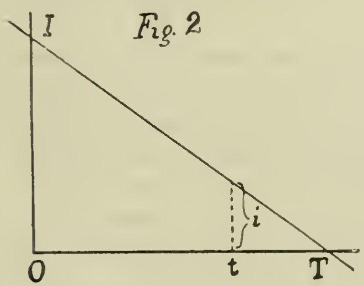
This estimate ranges among the highest of the estimates mentioned at the beginning, and since the lower estimates cannot be entirely discountenanced, I endeavored to find where I might have drawn an erroneous conclusion. There is only one proposition to which an error might be attributed, namely the assumed law that the radiation is in direct proportion to the temperature. It might be suggested that the radiation increases as the square of the temperature. At the first glance this supposition seems to be unwarranted, as apparently conflicting with former observations, but a closer investigation will disperse this objection. Assuming for a unit of radiation, the heat radiated from a perfect radiator of 1° absolute temperature, the radiation from the same surface when heated to the freezing point of water would be 273^2, and when heated 1° higher $(273 + 1)^2$. The difference $= 547$ is an equivalent of the heat exchanged between two surfaces of those temperatures. The exchange of heat between two surfaces of 0° and 10° (273° and 283° absolute) is 5560, which is very little more than ten times the former result. We see, therefore, the radiation is still approximately in proportion to the difference of temperature. For higher temperatures, however, the radiation would increase considerably, for instance, the exchange of heat between surfaces of 99° and 100° respectively, would be $373^2 - 372^2 = 745$.

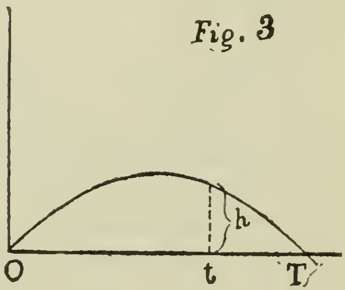
I thereupon searched in the library to find if former observations indicated such an increase, and in one text-book I found the statement that the radiation is approximately in proportion to the difference of temperature as long as this difference remains within certain limits, but that for greater differences the radiation increases more rapidly. Considering that most of the experiments were made with low temperatures and that the difference was increased by raising that of the radiating object, this statement seems to confirm my supposition.

There are, however, still other facts indicating that the radiation increases with a higher power of the temperature. The radiant heat

* It was not so much my object to arrive at a very close figure as to get a general insight. The following considerations will show that other questions will have to be answered first before we can even hope to arrive at a satisfactory result.

emanating from the sun is of a most complicated character, it being composed of innumerable series of rays of different order that can be dissolved by means of a prism, and can be projected upon a screen, where they form the spectrum, the luminous rays, of course, being regarded as heat rays capable of affecting the retina of the human eye. Heat, radiated from any object heated to incandescence, shows the same characteristic. When we watch the formation of the spectrum while the illuminating object is being heated, we first notice the appearance of the red rays, which then are very faint. As the heating is continued, the orange, then the yellow, the green, and finally, also, the blue and violet portion of the spectrum is developed, while at the same time the red portion is growing more intense. We may infer from this observation that the various orders of rays are due to various temperatures, and besides, that as the heating is continued, not only new series of rays are added, but the rays due to lower temperatures are intensified.





There is no reason why this inference should not also be extended to the non-luminous rays, or rays due to lower temperatures, and hence, a compound ray emitted from an object of the temperature T can be represented by the triangle $O\ I\ T$ (Fig. 2) where the ordinate $O\ T$ measures the order, and the abscissa $O\ I$ the intensity of the component ray. In this diagram it is assumed that the intensity of any of the component rays due to the temperature t is $i = (T - t)\ .\ c$. The caloric value or heating quality of any of the component rays is equal to the product of the intensity into the appertaining temperature, and is therefore $h = t\ (T - t)\ .\ c$, which is the equation of a parabola. Consequently, if we lay out another diagram showing the caloric value of the different component rays, its form will be as shown in Fig. 3, and we are thus led to the conclusion that different portions of the spectrum ought to show different heating qualities. This supposition

is fully confirmed by former observations, for this diagram reminds us decidedly of the caloric curve representing the heat developed in different parts of the spectrum.

This is, I believe, the first attempt of explaining the caloric curve of the spectrum on a purely logical basis, and this interesting development considerably encouraged me to proceed.

The next thing was to determine the total caloric value of the compound ray, which is $H = \int_0^T t(T-t)c.dt = \frac{c}{6} T^3$ and according to this formula the radiation increases even as rapidly as the cube of the temperature. The formula [1] will accordingly be changed to $T^{1^3} = T^3 + \alpha\tau^3$ and by substituting the values found by the experiment we find $\tau = 6670$, to which we have to add the initial temperature of the experiment (301° absolute), to obtain the solar temperature $=$ 6971° absolute.

Judging from the vast difference existing between this and the first estimate, the exact law of radiation has a great deal to do with the answering of the considered question, and the above theory should be tested before it can be accepted. Before all things the identity of the curve of Fig. 3, and the caloric curve of the spectrum should be demonstrated. Let us compare their maxima for this purpose. The maximum of the curve of Fig. 3 is evidently at $\frac{1}{2} T = 3485°$, and hence that of the caloric curve should be at a point of the spectrum corresponding to this temperature. But inasmuch as a heated object begins to emit red rays at about 900° abs. we may conclude that the ultra red rays in which the maximum of the caloric curve is located, are due to even less than 900°. The difference of these two figures does not speak very favorably for the foregoing speculation. It is true, the prism disperses the rays in an unequal proportion, spreading the rays of higher order more than those of lower orders. This would distort the caloric curve, and shift its maximum into the ultra red portion, while it may be located in the red rays; but this can hardly account for the above difference.

It will be remembered that in the foregoing calculation I assumed that the intensity of the individual rays was increasing in the same proportion as the temperature rises, and suspecting an error in this assumption, I tried other relations. By assuming $i = (T-t)^2 c$ I

obtained the curve of intensity as shown in Fig. 4, and that of caloric energy, as shown in Fig. 5. The formula, [1,] changes to $T'^4 = T^4 + a\tau^4$, and by substituting the values found by the experiment τ will be found $= 3335$, and the solar temperature $= 3635$, and the maximum of the curve of Fig. 5 $= \frac{T}{3} = 1212°$. Now it will be seen that Fig. 5 bears more resemblance to the caloric curve than Fig. 3, and the difference of its maximum and the figure supposed to represent the maximum of the caloric curve may be accounted for by distortion; at any rate these results are more satisfactory than those of my former calculation. It may however be, that the law of radiation is more complicated, and these theories are yet in the form of crude suggestions.

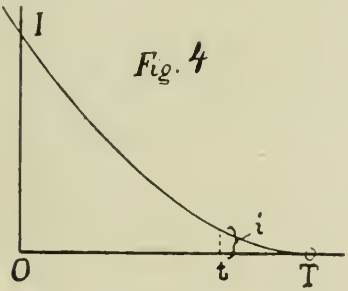


Fig. 4

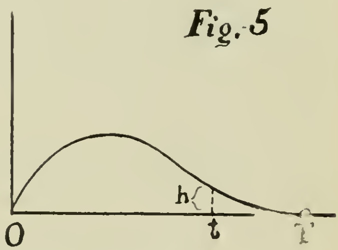


Fig. 5

My endeavors were next directed to finding additional means for corroborating the supposition that the radiation increases at a higher rate than the temperature.

Turning our attention to our first ideal experiment, it is evident that the object inclosed by two hemispheres of different temperatures should not assume a temperature equal to the arithmetical mean, as first supposed, but should rise to a higher point. If one of these hemispheres is at the freezing point, and the other at the boiling point of water, the calculated temperatures are 53·8°, 57·6°, and 61·1°, respectively, as we assume the radiation to be increasing as the square, cube, or the fourth power of the temperature.

I made preparations for a practical test, but not having at my command the means for producing a vacuum, I had to content myself without. I was well aware, though, that owing to the presence of air an exchange of heat by convection was inevitable, and the result of the experiment was accordingly impaired. However, as it can be safely assumed that the effect of convection tends to maintain the

arithmetical mean, a rising of the temperature of the inclosed object above this mean would indicate the tendency of the radiation. The experiment answered the question affirmatively, the thermometer rising to nearly 54°. Had the air been excluded the thermometer would presumably have risen to a higher point. Indeed, a series of such experiments made with different temperatures, in a vacuum, might disclose the exact law, however complicated that law may be.

In reviewing the preceeding, it appears rather curious that the estimates based on one single experiment range nearly from the highest to the lowest of the estimates alluded to at the beginning. Of all these figures the last one seems to be the most reasonable, for there exists a striking similarity between the solar light and that of the oxy-hydrogen flame or the electric light, and the temperatures of these latter lights are usually estimated at 3000° or thereabouts. Indeed, the lowest of the first mentioned estimates were based on a comparison of the solar heat with the heat emanating from a lime light, and the higher estimates having probably been based on a misconception of the law of radiant heat, the proposed theory may be the means of reconciling the conflicting estimates.

In summing up it will be seen that in support of my theory can be offered:

1. The result of the last mentioned experiment.
2. The ready explanation of the caloric curve of the spectrum.
3. The prospect of bringing to unison the conflicting estimates of the solar temperature.

My attention was not only directed to the temperature of the sun, but also to its relation to that of our earth, and I shall select the last law and estimate as a basis for the figures used to exemplify the conclusions bearing on this subject.

If the globe of a thermometer was suspended in space at a distance from the sun equal to that of our earth, its temperature would become $t = \sqrt[4]{\frac{T^4}{184650}} = 175°$ abs. $= -98°$; the heat it would receive from the more distant stars being disregarded. In exposing a flat plate of non-conducting material at right angles to the sun, the side facing the sun would attain a temperature $t = \sqrt[4]{\frac{T^4}{46162}} = 228$ abs. $= -25°$.

The surface of the moon is exposed to similar conditions and will

accordingly, during the long lunar day, be heated to a point never exceeding —25°, while the average temperature of the moon would be —98°. But how does this speculation agree with the temperature of our earth? Indeed, the old question as to the cause of the cold on high mountains is now reversed. We have to inquire why it is so warm there, and why it is still warmer in the lower regions. The interior heat of the earth cannot account for this great difference. An answer to this question is, however, not very remote. In exposing a thermometer to the clear nocturnal sky, we find that notwithstanding the greatest care in guarding it from receiving heat by any ways other than radiation, the temperature of the air has a decided influence upon that indicated by the thermometer. The air must therefore be capable of radiating heat and cannot be transparent for rays of the same character, although it is transparent, almost to perfection, for rays of higher order, for luminous rays. Only a portion of the solar rays penetrate the atmosphere and strike the earth, which partly reflects, partly absorbs them and return the heat appropriated by absorption in form of rays of lower order.

To these rays the atmosphere is opaque; they are accordingly absorbed, and retained near the surface of the earth. The action of the atmosphere can thus be compared with the action of valves, admitting heat freely, but preventing its escape.

The effect would be a continual increase of heat near the surface of the earth, which, however, is balanced by convection of heat to the outskirts of the atmosphere, from whence it is radiated and lost into the universe. But convection being comparatively slow, a surplus of heat will prevail in the lower regions.

I concluded that if this theory be correct, a piece of blackened metal exposed to the sun, would ultimately be heated to a higher degree when covered by a flat piece of glass than when uncovered; for the glass would act in the same manner as the atmosphere. In order to test this, it was my intention to procure a suitable piece of glass from an optician, but upon stating the purpose for which I wished to use it, I was informed that the fact was observed before, and then I thought it unnecessary to repeat the experiment.

In a recently invented solar boiler (Mouchot's), advantage is taken of this fact. The boiler upon which the solar rays are concentrated by a reflector, is enveloped by a glass bell. The rays of higher order of

the sun are readily transmitted, but those of lower order returned by the boiler, are arrested and thus retained inside of the bell.

Returning to the subject, it appears now that the thickness and condition of the atmosphere govern in a great measure the temperature of the earth, and a number of inferences can be based on that theory.

Carbonic acid being a better absorber of heat, by many times, than either oxygen or nitrogen, the small percentage of this gas in the atmosphere may have a great deal to do with our temperature. At a past period the percentage of this gas may have been less than at present. This might explain the glacial period. Before the immense fields of coal were deposited under ground, the air must have been richer in carbonic acid, and hence a better protector of heat. This may account for the luxury and abundance of vegetable growth of that period.

Thus my studies were carried farther than I originally intended, but it is almost impossible to investigate any subject without being led on other topics. The laws of nature are so closely related to each other, that no line of division can be drawn, and one discovery suggests another.

A STANDARD GAUGE SYSTEM.*

By George M. Bond, Hartford, Conn.

In a paper presented at the May meeting of the Society last year, a statement, or "report of progress" was submitted, showing the method adopted by the Pratt & Whitney Company, of Hartford, Conn., by which the question of practically establishing a standard for size gauges was to be scientifically determined, accurately subdividing the Imperial yard into feet and inches and fractional parts of an inch, and describing briefly the extent to which was carried the scientific research found absolutely necessary for such an undertaking; it remains now to present to the consideration of those who may be interested, a statement of the results proceeding from the practical application of all the thorough, conscientious investigation of Professor Rogers, of Harvard College Observatory, whose invaluable experience and professional services, in obtaining for the company the transfer and subsequent subdivision of the British yard, gave the foundation for

*From advance sheets of the transactions of the American Society of Mechanical Engineers.

what has been accomplished, enabling the company to feel warranted in earnestly inviting an inspection of the means now available for the production of standard sizes, and asking for it the endorsement of the engineering profession, should it be found worthy of such necessary support.

The comparator referred to in the previous paper, has been placed in position upon brick piers in a room outside the main building, erected especially for it, and is comparatively free from the jar and tremor of the machinery, even unaffected by the jar of passing trains (the tracks of the New York, New Haven and Hartford, and of the New York and New England Railroads being quite near), the rigidity of the instrument and the excellent workmanship in its construction preventing any perceptible vibration during an observation, even when the high power microscopes, magnifying 150 diameters, are used.

The illumination required in using these microscopes is perfectly attained by reflection, using a plate-glass mirror placed outside of the window of the comparing room, at an inclination of 45 degrees, giving clear diffused light, cloudy weather even improving the general effect, as the light is then whiter than that reflected from a clear blue sky, and the lines on the standard bar, as seen through the medium of the Tolles' illuminating prisms with which the objectives are fitted, are clearly and sharply defined at any time during daylight, and in any position of the microscope plate; by thus avoiding the use of artificial light and consequent effect of a variable temperature, far more satisfactory results are obtained.

The investigation for the determination of the necessary corrections for errors due to horizontal or vertical curvature of the path of the microscope plate, has shown conclusively the unexcelled workmanship in the construction of the comparator; as an instance of how slight these errors really are, it was found after repeated observations, the means being carefully collected, that the horizontal curvature, *i. e.*, the bending sidewise of the cylindrical guides or ways upon which the microscope plate slides, at the part investigated, was that having a radius of *eleven miles*, and a consequent correction to be applied of about one ten-thousandth of an inch in 18 inches, the latter distance referring to the position of the measured standard when placed either side of the line of motion of the centre of the microscope plate, moving between fixed stops, and which is the constant quantity to which is referred the subdivisions of the standard bar; as the microscope is usually within

one inch, rarely over two and a half, from the centre line of the stops or caliper jaws between which the end measure pieces or the cylindrical gauges are placed, this correction evidently becomes too small to be applied practically, within the limit of a six-inch gauge; for a foot or a yard it would become necessary, as the variation of the chords of the subtended arcs then becomes quite perceptible. The errors due to inequality of temperature in the standard steel bar and the hardened steel end-measure gauges must be carefully guarded against, the latter effect being far more important, practically, and often very misleading. In the case of a four-inch hardened steel end-measure gauge experimented upon, the coefficient of expansion being nearly one one-hundred thousandth of its length, one degree of change of temperature from that maintained in the reference bar, introduces an error of nearly one twenty-five thousandth of an inch in the total length, and hence, as a change or inequality of five or even ten degrees might be easily overlooked, the four-inch gauge would be found to be from one-five thousandth ($\frac{1}{5000}$) to one twenty-five hundredth ($\frac{1}{2500}$) of an inch too short, when equality of temperature is restored; when it is asserted that an actual variation of so minute a quantity as *one thirty-thousandth* of an inch, and even less, can be readily detected by any tool-maker familiar with the use of an ordinary micrometer or a close gauge, the importance of keeping *within* this limit is apparent,—of course, this shortening effect is not so marked in smaller sizes, still the ratio is the same, and this error must be carefully avoided.

The subdivisions upon the six-inch hardened steel standard bar have been carefully investigated upon the new comparator, to determine how nearly these inch spaces equal each other, the total length of the four inches which are ruled upon this six-inch bar being *exactly standard* at 62 degrees Fahrenheit, according to the official report of Professor Rogers, received December 1st, 1881, and in this report, the results obtained by him, determining this relation of the inch spaces to each other, was found to agree closely with the results obtained by me, as the following comparison will show, these minute corrections being necessary in accurately determining the subdivisions of the Imperial yard, which they represent:

Corrections.	Prof. Roger's Report.	Results obtained.	
Total 1 inch, *add*,	0.000008	0.000008	($\frac{1}{36}$ yard.)
Total 2 inches, *subtract*,	0.000026	0.000027	($\frac{1}{18}$ ")
Total 3 inches, *subtract*,	0.000005	0.000006	($\frac{1}{12}$ ")
Total 4 inches,	correct	correct	($\frac{1}{9}$ ")

The results given in the last column are the *means* of a number of observations, taken at different times and under various conditions of temperature, etc., and cover a period of about four weeks, the final results having been obtained December 31st.

The value of the divisions of the micrometer employed was carefully determined in order to reduce them to the same unit used by Professor Rogers, and was found, using the microscope marked "B," to equal $\frac{1}{58500}$ of an inch (0.000016, nearly).

When it is considered that the two results were obtained under different conditions, and using different microscopes, and with comparators differing in construction, the correctness of the *principle* upon which the comparison is founded, certainly needs no other proof.

The method of obtaining this relation of the separate inches upon the six-inch standard, was referred to in the former paper, and is that of comparing each inch with a constant distance moved over by the microscope plate between fixed stops, a constant pressure of contact being obtained by the use of electro-magnets, the separate inch spaces being thus referred to an *invariable* quantity or distance, and their relation to each other consequently determined.

To explain more fully this operation, the method adopted is as follows: A series of readings is taken at the zero or initial line of the first inch space, using the micrometer referred to, the microscope plate being held firmly against the fixed stop by the electro-magnet; the microscope then moves with the sliding plate until the latter is in contact with the other fixed stop, and held by the electro-magnet, the plate having moved as nearly an inch as it may conveniently be done,—generally a little more than an inch, in order to have the *sign* of the reading always the same,—from three to five readings of the micrometer are then taken at each position of the microscope, and the order reversed, to eliminate possible error; the first inch is thus compared with a fixed quantity, and the same operation repeated for the remaining inch spaces.

The difference between the distance moved by the microscope plate and the distance between the defining lines representing inches, is found by subtracting the *means* of the readings obtained, and thus eliminating the possible error of any single observation.

The following is a series of micrometer readings, and comprises the means of all the observations by which the corrections of the separate inches were obtained, illustrating the system adopted, and which has

been used invariably by Professor Rogers in his investigations of the subdivisions of the yard and meter bars, now in the possession of the Pratt and Whitney Company.

COMPARISON OF INCHES.

	L.	R.	L.	R.	
	58.1	65.8	58.0	65.5	Reverse order.
1st inch	58.6	66.0	58.1	65.8	
	58.5	65.4	58.0	65.8	
Mean	58.4	65.7	58.0	65.7	
	58.0	65.7			
Mean	58.2	65.7			

$R - L = + 7.5$ divisions of micrometer.

	L.	R.	L.	R.	
	56.2	65.8	55.4	65.4	Reverse order.
2d inch	55.6	65.8	56.0	65.4	
	56.2	66.0	55.4	66.0	
Mean	56.0	65.8	55.6	65.6	
	55.6	65.6			
Mean	55.8	65.7			

$R - L = + 9.9.$

	L.	R.	L.	R.
	55.0	63.0	57.0	63.0
3d inch	55.8	63.0	57.0	63.5
	55.7	63.6	57.0	62.8
Mean	55.5	63.2	57.0	63.1
	57.0	63.1		
Mean	56.3	63.1		

$R - L = + 6.8$

	L.	R.	L.	R.
	57.4	64.3	56.0	64.2
4th inch	57.8	64.8	56.1	64.5
	57.8	64.8	56.8	64.5
Mean	57.6	64.6	56.3	64.4
	56.3	64.4		
Mean	56.9	64.5		

$L - L = + 7.6$

CORRECTION Σ

$+ 7.5 + 0.45 + 0.45 =$ correction for first inch.

$+ 9.9 - 1.95 - 1.50 =$ correction for total 2 inches.

$+ 6.8 + 1.15 - 0.35 =$ correction for total 3 inches.

$+ 7.6 + 0.35 \pm 0.00 =$ correction for total 4 inches.

Mean $+ 7.95$

The differences of the observed inch spaces with respect to the constant quantity obtained by the motion of the microscope plate, are added and their mean taken, from which the corrections are determined with the proper signs; in order to check the accuracy of the latter work, these corrections are added, the final result being evidently zero, the column under "Σ" showing this algebraic sum.

It may be appropriate here to state that the six-inch bar upon which these four-inch spaces are traced, is a standard which is, without doubt, the only hardened steel *line-measure* bar in existence, which is exactly one-ninth part of the Imperial yard at 62° Fahrenheit, and Professor Rogers considers it as such in his report, before referred to.

In order to apply these subdivisions, which include all sizes, from one-sixteenth of an inch to four inches, varying by sixteenths, to a practical form, fixtures have been provided and are in constant use, for reducing to *end* measure the distances thus accurately spaced, and a caliper attachment has lately been added from plans proposed by Professor Rogers, by which the diameter of existing cylindrical gauges, as well as the length of end-measure pieces from one-sixteenth of an inch to six inches may be tested with the same precision that characterizes the investigation of the linear spacing of the standard bar, also providing means for a rigid inspection of finished gauges before they leave the works, thereby insuring uniformity.

To illustrate how nearly alike two pieces may be made, two standard inch end-measure gauges were worked down under the microscope, independently of each other, using the lines upon the ruled standard reference bar and the fixture referred to, which, when compared with each other by the most careful tests, using close or "snap" gauges, and tested thus by tool-makers experienced in work requiring the utmost practical precision, neither piece could be singled out as the larger, the effect of unequal expansion caused by temperature being avoided during the test. Under the microscope, both pieces were found to be exactly alike by a *single* observation, while the comparison, by a series of readings showed a mean difference between the two pieces of one-tenth of a division of the micrometer, and when it is remembered that one division has a value of only $\frac{1}{58500}$th of an inch, the duplication, it may be assured, is certainly satisfactory, and is clearly within a practical, if not a theoretical limit of accuracy.

Having thus the means for closely reproducing established sizes, and no possible wear occurring to the bar from which these sizes are taken, the accurate duplication becomes a comparatively simple operation.

In order to produce standard work within the limit of a yard, or a meter, there has been furnished by Professor Rogers, two steel yard and meter bars, referred to in the previous paper, one of these bars tempered, the other being left soft, but having hardened steel plugs, which are adjustable, for the purpose of bringing the surfaces into focus under the microscope; upon these hardened plugs the lines are ruled, both bars having line and end-measure, thus providing means for testing the accuracy of the pitch of screw threads of any desired length, and for standard length gauges up to thirty-six inches, or to a meter.

The coefficient of expansion has been determined for each by Professor Rogers with the most scrupulous exactness as stated in his report, and also the relation, at 62°F., between these steel bars and the two bronze standards, both of which are line measure, (the latter are described in the paper previously referred to) so that gauges of any size may be made almost independently of temperature, other than the care required in keeping this condition as nearly uniform as possible for both the reference and the measured bar during the time of the transfer, or the determination after having been transferred.

The subject of accurately producing standard leading screws is receiving its share of attention, and those who use micrometers will readily understand its bearing upon the precision with which they may be made, and how unsatisfactory because of the necessary corrections to be applied in many instances, even when standard at some one part of the divided head—a uniform lead or pitch of the screw, however much may be the total error (within a reasonable limit), making a great improvement in their construction.

Besides a complete set of end-measure gauges, varying by sixteenths from one-quarter to four inches, there is now ready for inspection a complete plant, consisting of tools and fixtures for producing the standard United States or Franklin Institute thread gauges, every detail having been carefully considered, and every difficulty overcome in the operation for perfecting, not only these standard gauges as to size, but the pitch of the thread, the correct angle, and the width of flat at the top and bottom of the thread. The accuracy of this work is now open to the inspection of all who may be interested, and rapid duplication by *machined* work is now an assured success.

It is the conviction that the "bottom" has finally been reached, that warrants the Pratt and Whitney Company in thus inviting a

thorough inspection of the means available, and the methods employed, for producing standard gauges, and earnestly desiring an impartial verdict as to its accuracy and practicability, whether or not, the system as adopted and carried out, has any real merit upon which the confidence of those using gauges for interchangeable work may be safely based.

DISCUSSION.

PROFESSOR ROBINSON: This paper is of the highest merit and of the greatest possible interest to members of the Society, and it is a matter of great satisfaction to the mechanical engineers of this country that there is some one who is able to take hold of this question and treat it so ably as it has been treated; and inasmuch as the methods and results, as stated by the reader, are laid open for inspection by others, I think it is due, in consideration of the amount of effort and expense which has been given to this matter, that the Society, as a matter of duty, should appoint a committee to avail itself of the privileges offered of investigating this, and of making such a statement regarding it as will be found advisable; and undoubtedly this is a thing which the Society will be willing and anxious to endorse in every particular as a standard of the country. For one, I should be glad to see a committee appointed to give this matter the attention it deserves.

PROFESSOR EGLESTON: I notice that there is no reference in this paper to any instrument in the shape of a caliper of any kind used as a gauge. I do not know whether the members of the Society are familiar with the fact that in 1875 the Institute of Mining Engineers appointed a committee on standard gauge, and that committee came to just exactly the conclusion which is expressed here, that diameters or linear measures ranging in fractions of a millimeter or an inch were the only gauges which were standard or could be standard. It is a peculiar gratification, as a large part of the work fell to my hands, to see that idea so fully sustained. It is a matter of a great deal more importance than perhaps would appear just now. I believe the English engineers are again agitating the question of standards, and are going back to the old caliper idea. So I have heard recently. So I think it is really a retrograde movement. Most of you may know the fact, but we discovered in the course of our investigations

that if you take a dozen standard gauges, so-called, out of any package, you will find no two of them alike.

The President: I suppose the members would be interested if Mr. Pratt would tell us how they went to work in this undertaking. Mr. Pratt told us the story at Hartford, but many gentlemen are here to-day who were not with us then, and I presume it would be very interesting to all to know how Messrs. Pratt and Whitney were led into this prolonged, expensive, and nice investigation.

Mr. Pratt: I will relate the story in the briefest possible way. We were called upon to furnish a set of standard thread gauges, and of course the first thing to do was to get the sizes, and upon examining the different makes of gauges we found no two sets alike, and we were forced to commence, as we thought, at the bottom, and at that time, in sending about a foot-piece that we had obtained, we found that those investigating it did not agree upon its value. Among others Professor Rogers was applied to, to investigate the foot-piece, and he had quite a struggle over it with some of our prominent manufacturers of gauges. They could not agree, and Professor Rogers took it upon himself, at his own expense, to go to Europe, and go to the bottom of the thing. He visited the best authorities in Europe, and spent four months there in investigation. After we had obtained the services of one of the graduates of the Stevens Institute, and in connection with Professor Rogers, we constructed two comparators, one of which Professor Rogers has himself, and one of which we have; they being exactly alike. After Professor Rogers returned he investigated the foot-piece, and found it to be about what he had found it to be before, and then, after the new comparator was finished, he found his statement verified. Previous to this time, fortunately, Professor Rogers had been for several years constructing a ruling machine, and he had it completed about this time. We have gone very carefully into this thing. I do not feel egotistic about it at all. What we want is that every one who is interested in the matter, every society that takes any interest in it, should come and examine our methods and our measurements. If they are good, let us have a standard. If they are not, let us throw them away. It has cost us probably twenty thousand dollars to-day, and I am willing to throw it away if anybody can show us better. We want a standard, and I will not stand in the way of any one else

who has a better machine. I feel very much interested in the subject, myself; and I think we shall succeed in what we have undertaken.

Supply of Air to Houses.—MM. Autier and Mongey have devised plans for the distribution of cool, fresh air to houses. The former proposed to employ a feeble pressure, while the latter recommends a pressure of five or six atmospheres, together with special refrigeration, in order to obtain increased cold by expansion, on the plan of the frigorific engines of Windhauser, P. Gifferd, etc. The Holley system, as employed by the Steam Supply Company in Lockport, is quoted as an evidence of the economy of large public provisions for the distribution of such means of family comfort as heat, gas, fresh air, and relief from the oppressive heats of summer. The distribution of such air would not only contribute to bodily comfort and public health, but it would also retard the fermentations and decompositions of animal and vegetable substances, and it might, at the same time, be employed to furnish motive power.—*Chron. Industr.* C.

AN EXTENSION OF THE THEOREM OF THE VIRIAL AND ITS APPLICATION TO THE KINETIC THEORY OF GASES.*

By H. T. Eddy, C. E., Ph. D., University of Cincinnati.

1. Introductory.

Clausius published, in 1870, a paper upon a *New Mechanical Theorem Applicable to Heat*,† which he designated as the *Theorem of the Virial*, and which he applied to the stationary *progressive* motion of the molecules of gases.

The object of this paper is to demonstrate an analogous theorem applicable to the stationary *rotary* motion of the molecules of gases, and by the aid of these two theorems to improve, to some extent, the kinetic theory of gases, especially in removing an heretofore inexplic-

* From the Scientific Proceedings of the Ohio Mechanics' Institute, for March, 1883.

† Berichte der niederrhein. Gesellsch. für Natur u. Heilkunde, Juni, 1883. Phil. Mag., Series 4, vol. 40, 1870, p. 122. Pogg. Ann., vol. 141, p. 124.

able contradiction between the theoretic and experimental values of the ratio of the specific heats of a gas. To accomplish this most simply, it has seemed best to repeat here, in the first place, the more important parts of Clausius' original investigation, which he has supplemented by a number of important papers which have been translated and published in the *Philosophical Magazine*, between 1870 and 1876. Of these papers, the one most closely related to the original paper is one "*On Different Forms of the Virial.*"*

2. Clausius' Theorem respecting Stationary Progressive Motion.

A material system is said to be in stationary motion when the bodies of which it is composed do not continually depart from their initial positions, and their velocities do not continually recede from their initial values. The molecules of a gas in equilibrium are regarded as constituting such a system. For the sake of definiteness, let the system of molecules under consideration be that constituting one unit of mass of gas contained within impervious walls, although the same laws will evidently hold in case the walls are merely imaginary boundaries conceived as separating the unit of gas from other surrounding units. Let m be the mass of any molecule of this gas, and $x\,y\,z$ its rectangular co-ordinates referred to any origin; let $X\,Y\,Z$ be the components along the axes of xyz respectively of the resultant of all the external forces acting upon the molecule m, taken as positive, when they tend to increase the co-ordinates $x\,y\,z$ respectively.

Now, by the principles of the differential calculus, we have the identical equation,

$$\frac{1}{2}\,\frac{d^2(x^2)}{dt^2} = \frac{d}{dt}\left(x\,\frac{dx}{dt}\right) = \left(\frac{dx}{dt}\right)^2 + x\,\frac{d^2x}{dt^2}, \tag{1}$$

as may be seen by performing the differentations expressed in the first two terms.

But by the fundamental equations of dynamics expressing D'Alembert's principle:

$$m\,\frac{d^2x}{dt^2} = X. \tag{2}$$

Substitute from (2) in (1), etc.

$$\therefore\ \frac{m}{2}\left(\frac{dx}{dt}\right)^2 = \frac{m}{4}\,\frac{d^2(x^2)}{dt^2} - \frac{x}{2}\,X. \tag{3}$$

* Phil. Mag., Series 4, vol. 48, 1874, p. 1.

The first member of (3), being one-half the product of the mass by the square of the velocity along x, expresses the energy of progressive motion of m parallel to x at any instant when its co-ordinate is x, and the force moving it in that direction is X.

In order to find the mean or average value of this energy during any interval of time t, (3) must be multiplied by dt, integrated between the limits 0 and t, and then the result divided by t, this being the ordinary process for finding the mean value of any function for the time t.

$$\therefore \frac{m}{2t}\int_o^t \left(\frac{dx}{dt}\right)^2 dt = \left\{ \left(\frac{d(x^2)}{dt}\right)_t - \left(\frac{d(x^2)}{dt}\right)_o \right\} - \frac{1}{2t}\int_o^t x\,X\,dt. \qquad (4)$$

The two integrals in (4) are, as just stated, expressions for the mean values of the corresponding expressions in (3): but the quantity not under the integral sign is of a different nature; it is the difference between the final and initial values (as expressed by the subscripts) of a function whose final and initial values may (if t be properly chosen) be equal, in which case the difference would vanish. But it is unnecessary so to choose t that the difference vanishes; for, by reason of the divisor t, it appears that if t be taken sufficiently large, the term under consideration vanishes, even though the final and initial values are not equal, since they cannot recede indefinitely from each other. That they cannot so recede appears from the identical equation, obtained in the same manner as (1):

$$\frac{d(x^2)}{dt} = 2x\,\frac{dx}{dt}, \qquad (5)$$

from which it appears that the expression under consideration is dependent upon the products of quantities (co-ordinates and velocities) which, by the definition of stationary motion, cannot recede indefinitely from their initial values.

Let now $x\,y\,z$ denote no longer the co-ordinates of m at any particular instant, but, instead, their mean values during the time t; and, similarly, let $X\,Y\,Z$ denote mean values, and let $x'y'z'$ be the corresponding mean velocities along the axes. Hence, we may write (4), and the two similar equations with respect to the axes of y and z, as follows:

$$mx'^2 = -x\,X, \quad my'^2 = -y\,Y, \quad mz'^2 = -zZ, \qquad (6)$$

in which, as just stated, the variables express mean values during the interval t, which may be taken so large as to give them sensibly constant values.

Let the unit of gas under consideration consist of n molecules, which

may have equal or unequal masses; then equations like (6) apply to each of the n molecules, whose masses may be distinguished one from another by giving to m successive subscripts from 1 to n. Suppose these equations formed, and take their sum:

$$\therefore \tfrac{1}{2} \Sigma_1^n m(x'^2 + y'^2 + z'^2) = -\tfrac{1}{2} \Sigma_1^n (xX + yY + zZ). \tag{7}$$

The first member of (7) is the kinetic energy of the progressive motion of the members of the systems, and the last member is called the *virial* of the system, and depends for its value upon the mean forces acting upon the molecules and upon their mean positions.

The theorem which has now been demonstrated, may be thus stated: the mean kinetic energy of the progressive motion of a system in stationary motion is equal to its virial.

The forces which act upon the molecules of the gas will, in general, consist of two parts: the external forces, which may be taken to be the pressure at the surface of the walls of the enclosing vessel, and the internal forces, due to intermolecular attractions or repulsions. To compute the virial of the external pressure, let the closed surface containing the unit of gas under consideration be of any shape whatever. It is evident that the pressure exerted upon the enclosed gas in equilibrium will be normal to the surface. Let p be the pressure per unit of area, and let dS be the element of area of the enclosing surface, and l the cosine of the angle which the normal to the element makes with the axis of x. Also let $X = X' + X''$, in which X' is the part of the total component force X, which is due to the pressure p, and X'' is the remainder of the component X, due to internal attractions, etc. It is to be noticed that the sign of p is opposite to that of X', because p tends to cause the molecules to approach each other, while X' tends, when positive, to make them recede from the origin, and so from each other. Then $l\,dS = dy\,dz$.

$$\therefore \quad -\tfrac{1}{2} \Sigma_1^n xX' = \tfrac{1}{2}\int xpl\,dS = \frac{p}{2}\int\int x\,dy\,dz. \tag{8}$$

In (8) the single integration in the second member is to be extended only over the enclosing surface, for those molecules alone are acted upon by the pressure which are at the surface; but the double integration in the last member is to be extended throughout the whole volume v enclosed within the surface. In fact, the double integral in (8) expresses the total enclosed volume v occupied by the unit of gas:

$$\therefore \quad \text{by (8)}, -\tfrac{1}{2} \Sigma_1^n xX' = \tfrac{1}{2} pv, \tag{9}$$

with similar equations for y and z, which, being added to (9), give the total virial due to the external pressure to be

$$-\tfrac{1}{2}\,\Sigma_1^n(xX'+yY'+zZ')=\tfrac{3}{2}pv. \tag{10}$$

In order to compute the part of the virial due to intermolecular forces, let R be the attractive force between any pair of molecules, as m_1 and m_2, and let r be the distance between them; then is $(x_1-x_2)\div r$ the cosine of the angle which the attraction with which m_1 is drawn towards m_2 makes with the axis of x;

$$i.e., \quad -X_1''=\frac{x_1-x_2}{r}R, \text{ etc.}$$

$$\therefore\ -(x_1X_1''+x_2X_2'')=x_1\frac{x_1-x_2}{r}R+x_2\frac{x_2-x_1}{r}R,$$

$$\therefore\ -(x_1X_1''+x_2X_2'')=\frac{(x_2-x_1)^2}{r}R, \tag{11}$$

with two similar equations with respect to the axes of y and z.

Now take the sum of the three equations similar to (11) for each different pair of molecules in the system between which intermolecular forces exist, and noticing that

$$(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2=r^2, \text{ etc.}$$

the virial of the intermocular forces becomes

$$-\tfrac{1}{2}\,\Sigma_1^n(xX''+yY''+zZ'')=\tfrac{1}{2}\,\Sigma rR. \tag{12}$$

The sum of the right-hand members of (10) and (12) is the total virial of the external pressures and intermolecular forces. Should there be other forces of sufficient magnitude to be of importance, as gravitation, electrical forces, etc., they must be also computed and added to this sum. Neglecting all these, we obtain from (7), (10) and (12),

$$\tfrac{1}{2}\,\Sigma_1^n m(x'^2+y'^2+z'^2)=\tfrac{3}{2}pv+\tfrac{1}{2}\,\Sigma rR. \tag{13}$$

3. A New Theorem Respecting Stationary Rotary Motion.

Let $A\ B\ C$ be the moments of inertia of any molecule of mass m, with respect to its principal axes.

Let $\dfrac{d\theta}{dt}, \dfrac{d\varphi}{dt}, \dfrac{d\psi}{dt}$ be the angular velocities about these principal axes, then are θ, φ, ψ angular co-ordinates with reference to some initial lines yet to be assumed.

Let LMN be the respective components about these same axes of the resultant of all the couples acting upon the molecule.

Then, by Euler's equation of rotary motion,

$$A \frac{d^2\theta}{dt^2} = (B - C) \frac{d\varphi}{d\,t} \frac{d\psi}{d\,t} + L, \tag{14}$$

with a similar equation with respect to each of the two remaining principal axes.

The following identity also holds:

$$\tfrac{1}{2} \frac{d^2(\theta^2)}{d\,t^2} \doteq \frac{d}{dt}\left(\theta \frac{d\theta}{d\,t}\right) = \left(\frac{d\theta}{d\,t}\right)^2 + \theta \frac{d^2\,\theta}{dt^2}, \tag{15}$$

as appears by performing the differentiations expressed in the first two members.

Substitute from (15) in (14), etc.:

$$\therefore \quad \tfrac{1}{2} A \left(\frac{d\theta}{d\,t}\right)^2 = \tfrac{1}{4} \frac{d^2(\theta^2)}{d\,t^2} - \tfrac{1}{2} (B - C)\, \theta \frac{d\varphi}{d\,t} \frac{d\psi}{d\,t} - \tfrac{1}{2}\, \theta L, \tag{16}$$

which, with a similar equation with respect to each of the two other principal axes, is an equation of rotation applicable to any solid body, in which the first member expresses the energy of rotation about the axis considered.

In order to apply (16) to stationary rotary motion, the mean value of its various terms must be found during the interval t, as was done previously in case of stationary progressive motion.

Let

$$\frac{1}{t} \cdot \int_o^t \left(\frac{d\,\theta}{d\,t}\right)^2 d\,t = \theta'^2,$$

then θ'^2 is the mean square of the angular velocity about the first principal axis.

The integral of the second term is

$$\frac{1}{2\,t} \left(\frac{d\,(\theta^2)}{d\,t}\right)_t - \frac{1}{2\,t} \left(\frac{d\,(\theta^2)}{d\,t}\right)_o$$

in which the subscripts denote the limits to be substituted. This expression vanishes ultimately, as appears from considerations like those adduced in connection with (4) and (5).

The mean value of the product $\frac{d\varphi}{d\,t} \frac{d\varphi}{d\,t}$, also vanishes, for it is evident that positive and negative angular velocities are equally frequent.

Let θ and L no longer denote particular values, but instead let them denote mean values of those quantities, and we have

$$A\,\theta'^2 = -\,\theta\,L, \quad B\,\varphi'^2 = -\,\varphi\,M, \quad C\,\psi'^2 = -\,\psi\,N, \tag{17}$$

Add these equations, and the sum for n molecules is

$$\therefore \tfrac{1}{2} \Sigma_1^n (A\,\theta'^2 + B\,\varphi'^2 + C\psi'^2) = -\tfrac{1}{2} \Sigma_1^n (\theta\,L + \varphi\,M + \psi\,N), \qquad (18)$$

in which the first member is the total rotary energy of the system and the second member can be reduced to a form like that which has been previously obtained for the virial in case of progressive motion. For let

$$L = \rho_1\,X', \quad M = \rho_2\,Y', \quad N = \rho_3\,Z', \qquad (19)$$

in which X', Y', Z' are the mean component forces acting upon the molecules, with the exception of the intermolecular attractions, and ρ_1, ρ_2, ρ_3 are the arms of the mean couples L, M, N, respectively.

Let

$$x = \theta\,\rho_1, \quad y = \varphi\rho_2, \quad z = \psi\,\rho_3, \qquad (20)$$

in which x, y, z are mean co-ordinates; then (20) will determine the initial lines from which θ, φ, ψ are measured.

By (19) and (20) we have

$$\Sigma_1^n (\theta\,L + \varphi\,M + \psi\,N) = \Sigma_1^n (xX' + y\,Y' + zZ'), \qquad (21)$$

$\therefore$ by (18),

$$\tfrac{1}{2} \Sigma_1^n (A\,\theta'^2 + B\,\varphi'^2 + C\psi'^2) = -\tfrac{1}{2} \Sigma_1^n (xX' + y\,Y' + zZ'). \qquad (22)$$

It is evident that the distribution of the kinetic energy of the system of molecules, both rotary and progressive, is effected by the encounters of the molecules with each other, and with the bounding surface. The progressive motion is also directly affected by the intermolecular attractions, while the rotations cannot be directly accelerated by these attractions, and this is the reason why they are not included in the forces entering the virial of rotation. When the inter-atomic attractions vanish, $X = X'$, $Y = Y'$, $Z = Z'$, and in all permanent gases these equations are known to be very approximately true.

Now by (10), which included only the external pressure, and by (22),

$$\tfrac{1}{2} \Sigma_1^n (A\,\theta'^2 + B\,\varphi'^2 + C\psi'^2) = \tfrac{3}{2}\,pv. \qquad (23)$$

Hence, by (13) and (23) we have for perfect gases

$$\tfrac{1}{2} \Sigma_1^n (A\,\theta'^2 + B\,\varphi'^2 + C\psi'^2) = \tfrac{1}{2} \Sigma_1^n\, m\,(x'^2 + y'^2 + z'^2) \qquad (24)$$

Equation (24) states that the mean progressive energy of the molecules is for perfect gases the same as their mean rotary energy. For imperfect gases, however, the energy of progressive motion differs very slightly from that of the rotary motion; a fact, the consequences of which will be more completely discussed in the latter part of this paper.

From this general statement of the equality of the mean rotary and progressive energy of the molecules, the special cases must, however, be excepted in which one or more of the couples L, M, N vanish identically. These couples may evidently all three so vanish when the molecules are in effect smooth spheres, and a single one of them may vanish in cases where the molecules may be regarded as smooth solids of revolution.

When $$L = M = N = 0$$

i. e., all three couples vanish, we have by (19)

$$\rho_1 = \rho_2 = \rho_3 = 0,$$

in which case equation (20) cannot be assumed to hold true. It appears, however, from (17) that in this case the energy of rotation about each axis vanishes.

In case a single couple, only, vanishes, let, for example, $L = 0$; then

$$\tfrac{1}{2}\,\Sigma_1^{\,n}(B\,\varphi'^2 + C\psi'^2) = -\tfrac{1}{2}\,\Sigma_1^{\,n}(yY' + zZ') = \tfrac{1}{2}\,\Sigma_1^{\,n}\,m\,(y'^2 + z'^2), \quad (25)$$

in which the first member is the mean total energy of rotation, and the last is two-thirds the mean total progressive energy, as is evident from the symmetry of the axes x, y, z.

Nothing has so far been said as to the amount of the kinetic energy of atomic vibration within the molecule, a question which we shall consider subsequently; but we may here remark that there is nothing in the preceding investigation of rotary motion which would lead us to restrict its application to those molecules alone in which A, B, C are constant, although it appears not unreasonable to suppose that the molecules of any substance are unchanged in their general character by change of state of aggregation, and that whether a substance be solid, liquid or gaseous, the molecules of which it is composed may be regarded as nearly rigid; *i. e.*, incapable of deformation to any considerable extent by finite forces, which is equivalent to supposing A, B, C nearly invariable. We shall therefore take the terms expressing mean energy of rotation to express mean values when the moments of inertia as well as the rotary velocities are subject to fluctuations of value consistent with the state of stationary motion.

That atomic vibrations do exist may be considered to be a fact from spectroscopic evidence, for the lines in gaseous spectra cannot be directly due to the very moderate progressive velocity of the molecules, but are rather to be ascribed to the intense vibrations set up within the

molecules by their mutual encounters, which vibrations would rapidly be extinguished by the energy they radiate, did they not also receive radiant energy from external sources.

Should any difficulties be felt as to admitting that the mean value of the last term but one in (16) vanishes, as was done in obtaining (17), it is to be noticed that whenever two of the moments of inertia of the molecule are equal, as for example $M = N$, then (17) hold from this consideration also, for then must the corresponding mean angular velocities be equal by symmetry, which with the equality of the two moments, M and N, is sufficient to insure the equalities expressed in (17).

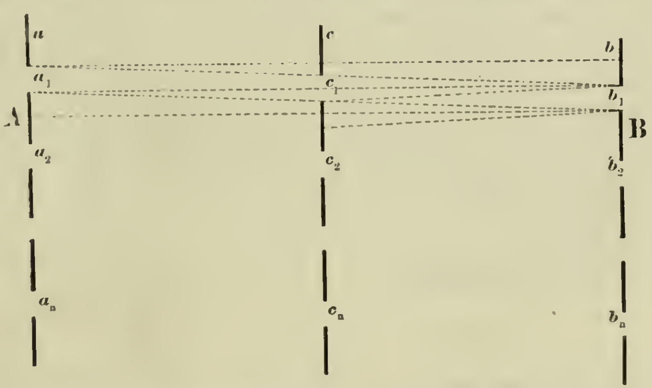
The hypothesis that $M = N$ must in many cases be correct, and it may perhaps be shown in all cases not to be far from the truth, when, as stated, (17) will hold for this reason alone.

(To be continued.)

SECOND LAW OF THERMO-DYNAMICS.

By De Volson Wood, M.A.

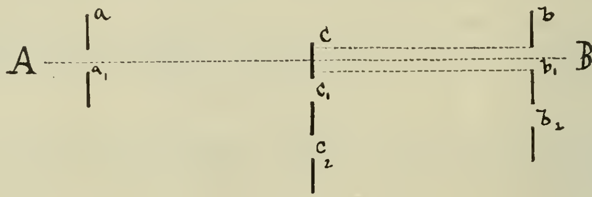
In the last number of this Journal is an article by Professor Eddy, in which he attempts to show how radiant heat may be made an exception to the second law of Thermo-dynamics; but it appears to us that the assumptions involve fallacies which are fatal to the proof.



We hold that it is *impossible* for a series of projectiles, or a train of projectiles, or a ray of light, or a ray of heat to pass from the body A freely through the opening of the screens and reach the body B as

claimed, and at the same time prevent those from *B* reaching *A*; and unless Professor Eddy can show that our position is erroneous, the supposed proof fails.

First, suppose that the mill is so constructed that the screen *c* will intercept all the rays from *B* passing through the openings b_1, b_2, etc., and are reflected back by the solid part of *c*.



Let all the spaces and openings be equal, and the screen *c* midway between *a* and *b*. The spaces in the screen *c* will not be exactly on the line of the openings a_1 b_1, but will be a little below that line, so that when all the screens are moved upward with the velocity and in the manner assigned by Professor Eddy, the spaces *c* will be on the line *A B* when the wave from *B* reaches *c*. Under these conditions no ray from *B* can pass the screen *c*. The rays being normal to the screens, it follows for the same reason that none of the rays from *A* can pass the middle screen if the openings in *a* are directly opposite those of *b*. If the openings in *a* are higher or lower than those in *b*, some or all of the rays passing through the openings in *a* will also go through *c* and pass on to the screen *b*, but there they will be intercepted by the solid part of the screen *b*. It follows then that *none of the rays from A can reach B if those from B are prevented from reaching A*. It scarcely requires any additional reasoning to show that *if the rays from A reach B, those from B will reach A*, and thus defeat the object of the inventor.

The *Second Law*, as stated by Clausius, is still valid, even with a finite velocity of propagation.

Stellar Photography.—By an exposure of 140 minutes, Draper has succeeded in photographing stars smaller than the fourteenth magnitude. He hopes to be able to photograph, ere long, stars which are too small to be seen in his nine-inch telescope.—*Les Mondes*. C.

PHOTODYNAMIC VIRIALS IN THE SOLAR SYSTEM.

By Pliny Earle Chase, LL.D.

The theory of the virial, or mean *vis viva* during stationary motion, enables us to co-ordinate all forms of cyclical motion, rotary, orbital and oscillatory. The grandest manifestations of the virial, which are given in cosmical motion, must be governed by the same laws as govern molecular movements. The complete development of the theory should, therefore, remove all the obscurity which still clings to the doctrine of radiodynamic unity.

A few cosmical illustrations will show the simplicity which considerations of mean energy introduce into the approximate solution of problems which would otherwise be exceedingly complicated. The illustrations are based upon the following postulates.

1. That cosmical masses represent internal energies, such as would be found if they were condensed from some primitive, tenuous, elastic form of matter.

2. That all chemical elements may have been condensed, in like manner, from a single primitive element, or æther.

3. That the velocity which enters into the primitive radial virial of the oscillating ætherial particles is the velocity of light (v_λ).

4. That the stationary motions of central inert masses, which represent the equal actions and reactions of primitive and derived virials, should continue until the velocity of the primitive virial has been alternately acquired and lost.

5. That all stationary motions which represent equal actions and reactions should be harmonic.

Solar or stellar centres of planetary systems, are central inert masses, which are endowed with velocities of stationary motion, tending to give velocities of stationary orbital revolution, sending forth æthereal oscillations with the velocity of light, and representing internal energies like those which would spring from nebular condensation.

Circular orbital velocity which is due to solar action, may be represented by the equation, $v_n = \sqrt{g_n r_n}$. 1

The limiting value of v_n, which it cannot exceed, is found at sun's surface (r_o), where g is a maximum. It may be represented by

$$[v_o] = \sqrt{g_o r_o} \qquad 2$$

The 3d and 4th postulates lead to the equation

$$g_\circ t_\circ = v_\lambda \qquad 3$$

This equation holds good for all values of r in an expanding or contracting nucleus, inasmuch as g varies as $\frac{1}{r^2}$, and the principle of conservation of areas requires that the time of rotation should vary as r^2. The product of the two factors should, therefore, be constant.

The rotating æthereal tendency of stationary motion, which is limited by equations (2) and (3), gives the following value for the limiting radius of orbital and æthereal tendencies.

$$\rho_\lambda = \frac{v_\lambda}{[v_\circ]} r_\circ = v_\lambda \sqrt{\frac{r_\circ}{g_\circ}} \qquad 4$$

Laplace's limit of equal rotary and orbital velocity (l) is given by the equation

$$l = \left(\frac{\rho_\lambda}{\pi r_\circ}\right)^{\frac{2}{3}} r_\circ = \left(\frac{\rho_\lambda r_\circ^{\frac{1}{2}}}{\pi}\right)^{\frac{2}{3}} \qquad 5$$

The limit at which the equatorial rotary velocity of stationary motion would give $[v_\circ]$ is

$$\left(\frac{l}{r_\circ}\right)^{\frac{3}{2}} r_\circ = \left(\frac{l}{r_\circ^{\frac{1}{3}}}\right)^{\frac{3}{2}} = \frac{\rho_\lambda}{\pi} \qquad 6$$

The limit at which the equatorial velocity of stationary motion would give v_λ, as deduced from (4) and (6), is

$$\left[\, l \,\right] = \frac{\rho^2_\lambda}{\pi r_\circ} \qquad 7$$

The limit of a homogeneous elastic æthereal atmosphere, which would propagate undulations with the velocity of light, is

$$M = \pi\,[l] = \frac{\rho^2_\lambda}{r_\circ} \qquad 8$$

The virials of rotating tendency must influence grosser inert particles or masses, as well as the æthereal atmosphere. Loci of important influence may be found at radii of mean æthereal momentum (ρ_α), of linear oscillation (ρ_β), of reciprocal linear oscillation (ρ_γ), of spherical oscillation (ρ_δ), and of reciprocal spherical oscillation (ρ_ε). Taking ρ_λ as the virial locus of these several oscillatory centres, we have

$$\rho_\alpha = 2\,\rho_\lambda \qquad 9$$

$$\rho_\beta = 1{\cdot}5\,\rho_\lambda \qquad 10$$

$$\rho_\gamma = 3\,\rho_\lambda \qquad 11$$

$$\rho_\delta = 2{\cdot}5\,\rho_\lambda \qquad 12$$

$$\rho_\iota = \tfrac{5}{3}\,\rho_\lambda \qquad 13$$

The tangential virial of an oscillating æthereal particle (μ_α), is $\frac{9}{5}$ of the radial virial of wave propagation for the same particle (μ_β). I first called attention to this relation in 1872.* Maxwell subsequently published it, apparently as an independent deduction, in 1877.†

$$\mu_\alpha = 1{\cdot}8\,\mu_\beta \qquad 14$$

An energy which is wholly transferred from one æthereal mass to another equivalent æthereal mass, must be accompanied by a like transfer of velocity, whether the transfer is through torsion (v_t), rotation (v_r), heat (v_θ), work (v_w), electricity (v_ε), or gravitation (v_γ).

We have, therefore, for limiting velocities,

$$v_\lambda = v_t = v_r = v_\theta = v_w = v_\varepsilon = v_\gamma \qquad 15$$

In cyclical movements which are due to virial transfers, these several equivalents may be indicated by equations analogous to (3).

In order to test the foregoing equations, let us take sun's semi-diameter ($r_\circ$) as the unit of length, and the British Nautical Almanac estimate of sun's apparent semi-diameter ($961''{\cdot}83$) as the parallactic unit. We then find, for earth's semi-axis major,

$$\rho_3 = 214{\cdot}45\ r_\circ. \qquad 16$$

Earth's mean orbital velocity (1) may be found by dividing $2\,\pi\rho_3$ by the number of seconds in a year (31558149). This gives

$$v_3 = {\cdot}000000199099\ \rho_3 \qquad 17$$

This value varies slightly with varying orbital eccentricity, but the greatest secular range of variation is less than $\frac{1}{8}$ of one per cent.

Circular orbital velocity varying inversely as the square root of the radius vector, we find (2) and (17)

* Proc. Amer. Phil. Soc., xii, 394. † P. Mag., iii, 453; iv, 209.

$$[v_0] = \cdot00000291562\ \rho_3 = \cdot000625255\ r_0 \qquad 18$$

$$g_0 = \cdot0000003909445\ r_0 \qquad 19$$

Struve's constant of aberration gives, by (3) and (19)

$$v_\lambda = g_0 t_0 = 214\cdot45\ r_0 \div 497\cdot827 = \cdot430772\ r_0 \qquad 20$$

$$t_0 = 1101876 \text{ sec.} = 12\cdot753 \text{ days} \qquad 21$$

This gives for a double oscillation, or complete rotation of sun, 25·506 days. Laplace's estimate was 25·5 days. The motion of sun-spots near the equator is accelerated, by centrifugal force, tendencies to orbital velocity, "repulsion," or some other unknown influence. Spörer's formula gives 24·62 days for the equatorial period.

From (4), (18) and (20) we find

$$\rho_\lambda = 688\cdot954\ r_0 = 3\cdot212654\ \rho_3 \qquad 22$$

From (5) $\quad l = 36\cdot366\ r_0 \qquad 23$

From (6) $\quad \rho_\lambda \div \pi = 219\cdot301\ r_0 \qquad 24$

From (7) $\quad [l] = 151088\cdot1\ r_0 = 704\cdot538\ \rho_3 \qquad 25$

From (8) $\quad M = 474657\cdot3\ r_0 = 2213\cdot37\ \rho_3 \qquad 26$

From (14) and (22) we find the following regular series of approximations to planetary loci. The subscripts, 1, 2, 3, denote, respectively, secular perihelion, mean, and secular aphelion.

$1\cdot8^{-4}\ \rho_\lambda$	= $\cdot3060\ \rho_3$	Mercury$_1$	=	$\cdot2974\ \rho_3$	27
$1\cdot8^{-3}\ \rho_\lambda$	= $\cdot5509\ \rho_3$	Venus$_1$	=	$\cdot6722\ \rho_3$	28
$1\cdot8^{-2}\ \rho_\lambda$	= $\cdot9916\ \rho_3$	Earth$_2$	=	$1\cdot0000\ \rho_3$	29
$1\cdot8^{-1}\ \rho_\lambda$	= $1\cdot7848\ \rho_3$	Mars$_3$	=	$1\cdot7365\ \rho_3$	30
$1\cdot8^{0}\ \rho_\lambda$	= $3\cdot2127\ \rho_3$	Asteroid 108	=	$3\cdot2120\ \rho_3$	31
$1\cdot8^{1}\ \rho_\lambda$	= $5\cdot7828\ \rho_3$	Jupiter$_3$	=	$5\cdot5193\ \rho_3$	32
$1\cdot8^{2}\ \rho_\lambda$	= $10\cdot4090\ \rho_3$	Saturn$_3$	=	$10\cdot3433\ \rho_3$	33
$1\cdot8^{3}\ \rho_\lambda$	= $18\cdot7362\ \rho_3$	Uranus$_2$	=	$19\cdot1836\ \rho_3$	34
$1\cdot8^{4}\ \rho_\lambda$	= $33\cdot7252\ \rho_3$	Neptune$_3$	=	$30\cdot4696\ \rho_3$	35
Geom'l Mean	= $3\cdot2127\ \rho_3$	Geom'l Mean	=	$3\cdot2200\ \rho_3$	36

All of these approximations represent loci of belt-condensation, for the respective planets, which are in accordance with the nebular hypothesis. The geometrical means differ by less than $\frac{1}{4}$ of one per cent. The photodynamic mean represents the semiaxis major of Asteroid 108; the planetary mean, the semiaxis major of Asteroid 122. The second photodynamic locus (.5509 ρ_3) is, within less than one per cent., the arithmetical mean between the semiaxes major of Mercury and Venus (·5552).

From (9), (10), (11), (12), (13), and (22) we get the following approximations:

$\rho_\alpha = 6{\cdot}4253\ \rho_3$	Cardinal centre	$= 6.4451\ \rho_3$	37
$\rho_\beta = 4{\cdot}8190\ \rho_3$	Jupiter_1	$= 4{\cdot}8863\ \rho_3$	38
$\rho_\gamma = 9{\cdot}6380\ \rho_3$	Saturn_2	$= 9{\cdot}5389\ \rho_3$	39
$\rho_\delta = 8{\cdot}0318\ \rho_3$	$\cdot 4\ \text{Uranus}_3$	$= 8.2717\ \rho_3$	40
$\rho_\epsilon = 5{\cdot}3545\ \rho_3$	Jupiter_2	$= 5.2028\ \rho_3$	41
Ar. Mean $= 6.8537\ \rho_3$	Ar. Mean	$= 6{\cdot}8690\ \rho_3$	42
Ge. Mean $= 6{\cdot}6325\ \rho_3$	Ge. Mean	$= 6{\cdot}6421\ \rho_3$	43

It will be seen from (40) that the second locus of spherical rotary projection from ρ_λ, ($2{\cdot}5 \times 2{\cdot}5\ \rho_\lambda = 20{\cdot}0795\ \rho_3$), is within the secular orbital range of Uranus. The cardinal centre (37) is the centre of gravity, at conjunction, of Saturn_2 and Jupiter_3. It represents, therefore, the locus of mean rotary momentum for their combined masses, at the time of Jupiter's incipient rupturing subsidence, according to Herschel's modification of the nebular hypothesis. It also represents important relations to the following additional virial loci.

$\rho_\zeta = \sqrt{\Sigma m\rho^2 \div \Sigma m}$	$= 9{\cdot}2443\ \rho_3$	44
$\rho_\eta = \Sigma m\rho \div \Sigma m$	$= 7{\cdot}5228\ \rho_3$	45
$\rho_\theta = \frac{1}{2}(\text{Saturn}_2 + \text{Jupiter}_3)$	$= 7{\cdot}5291\ \rho_3$	46
$\rho_\iota = \frac{1}{2}(6{\cdot}4451 + 8{\cdot}2717)$	$= 7{\cdot}3584\ \rho_3$	47
$\rho_\kappa = \frac{1}{4}\ \text{Neptune}_2$	$= 7{\cdot}5084\ \rho_3$	48

The locus of mean planetary nebular inertia (44) is in Saturn's orbit, where the rings, the satellite system and the specific gravity bear witness to the results of nebular condensation. The locus of mean planetary nebular momentum (45) approximates closely to the arithmetical mean between $Saturn_2$ and $Jupiter_3$ (46), to the arithmetical mean between the cardinal centre and the incipient virial locus of spherical rotation for Uranus (47), and to the virial locus for the mean linear momentum of Neptune's semiaxis major (48).

The virial radius of mean momentum not only determines the centre of gravity of the two chief planetary masses (9), (37), but it also determines the relative masses of Sun (m_0) and Jupiter (m_5) at initial nebular rupture (secular perihelion). We find, accordingly,

$$m_0 r_0 = m_5 \rho_{5,1} \qquad 49$$

Stockwell's estimate of Jupiter's secular eccentricity is .0608274. This gives $\rho_{5,1} = {\cdot}9391726 \times 5{\cdot}202798 \times 214{\cdot}45 = 1047{\cdot}872\, r_0$. Therefore, (49)

$$m_0 = 1047{\cdot}872\, m_5 \qquad 50$$

Bessel's estimate is 1047·879. This harmony is the more significant because Jupiter's nebular locus of incipient rupture (4·8863) is central between the loci of incipient subsidence of Uranus (20·6792) and Neptune (30·4696) at opposition,

$$\rho_{5,1} = \tfrac{1}{2}\left(\rho_{7,3} - \rho_{6,3}\right) \qquad 51$$

While Jupiter thus traverses the primitive nebular centre, Earth traverses the centre of the belt of greatest condensation.

$$\tfrac{1}{2}\left(\rho_{1,1} + \rho_{4,3}\right) = \rho_3 \qquad 52$$

Stockwell's estimates for the secular limits of the dense belt ($Mercury_1$ and $Mars_3$) are, $\rho_{1,1} = {\cdot}2974$; $\rho_{4,3} = 1{\cdot}7365$. This gives for (52) 1.0169 ρ_3.

While the rotation of the chief nucleal centre (Sun) is determined by the velocity of light (3), the rotations of the secondary centres of nebulosity (Jupiter) and condensation (Earth) are determined, respectively, by circular orbital velocities at Sun's surface $[v_0]$ and at the mean centre of gravity of Sun and Jupiter $[v_a]$.

$$g_5 t_5 = [v_0] = \sqrt{g_0 r_0} \qquad 53$$

$$g_3 t_3 = [v_a] = \sqrt{g_a r_a} \qquad 54$$

The data for the solution of (54) have been more accurately and satisfactorily determined than for (53).

$$g_3t_3 = \frac{32{\cdot}088}{5280} \times \frac{86164{\cdot}08}{2} = 261{\cdot}821 \text{ miles.} \qquad 55$$

Circular orbital velocity varying inversely as $\sqrt{r}$, we find (49), (50), (54), (55)

$$g_5t_5 = [v_o] = g_3t_3 \div \sqrt{.9391726} = 270{\cdot}167 \text{ miles.} \qquad 56$$

$$[v_3] = [v_o] \div \sqrt{214{\cdot}45} = 18{\cdot}449 \text{ miles.} \qquad 57$$

$$\rho_3 = 31{,}558{,}149\ [v_3] \div 2\,\pi = 92{,}662{,}000 \text{ miles.} \qquad 58$$

$$r_o = \rho_3 \div 214{\cdot}45 = 432{,}090 \text{ miles.} \qquad 59$$

At Earth's surface, $\sqrt{gr} = 4{\cdot}9073$. It varies as $\sqrt{\frac{m}{r}}$. Therefore, (57)

$$\frac{m_o}{\rho_3} : \frac{m_3}{r_3} :: 18{\cdot}449^2 : 4{\cdot}9073^2 \qquad 60$$

$$m_o : m_3 :: 330482 : 1 \qquad 61$$

All of the results which have been drawn from (3), (53), and (54) involve the principle of persistency of vibrations, by which waves tend to propagate themselves indefinitely, with the velocity which is due to their locus of origination.

The influence of Jupiter's locus of incipient subsidence on the comparative masses of Jupiter and Saturn, finds some analogy in the two chief planets of the dense belt, Earth and Venus.

$$m_2\rho_{2,3} = m_3\rho_3 \qquad 62$$

Substituting Stockwell's estimate of the secular aphelion of Venus ($\rho_{2,3} = {\cdot}7744234\ \rho_3$) in (61) (62),

$$m_o = 426750\ m_2 \qquad 63$$

Hill's estimate is 427240, which differs from (63) by less than $\frac{1}{8}$ of one per cent.

The general equation of fundamental velocity (15) rests on Laplace's principle of periodicity, "that the state of a system of bodies becomes periodic when the effort of primitive conditions of movement has disappeared by the action of resistances." Hence (3) (20),

$$v_\lambda = v_\gamma \qquad 64$$

The investigations of Weber, Kohlrausch, Thomson, Maxwell, Ayrton, and Perry have shown that

$$v_\prime = v \qquad 65$$

In Coulomb's formula of torsional elasticity, if we substitute $\frac{m}{2}$ for f, $gt^2 = M$ (26) and

$$gt = v_\lambda = v_t \qquad 66$$

In throwing a ball into the air, the thermal equivalent of the projectile force is equivalent to the product of the mass by the sum of the retarding resistances. In solar superficial radiation, the gravitating reaction, as we have seen (64), is exhausted in a half rotation. The corresponding projectile velocity may be regarded as representing, at pleasure, heat, work or rotation, giving

$$v_\lambda = v_\theta = v_w = v_r \qquad 67$$

Combining (64), (65), (66), (67), we find a practical confirmation of (15).

A NOTE UPON THE WORKING OF SULPHURIC ACID CHAMBERS.

By Henry Pemberton, Jr.

[A paper read before the Chemical Section of the Franklin Institute, March 13, 1883.]

During several years subsequent to the panic of 1873 a set of acid chambers, the property of a company of this city, was worked under my supervision. Owing to the depressed state of trade and consequent stock of goods on hand, the chambers were often run below their full capacity. They were run without a Gay Lussac absorbing tower, and burned best unmixed seconds brimstone, 4,000 pounds being the normal charge in 24 hours. Good results, approaching very nearly to the theoretical figures were obtained from such a charge when 10 per cent. nitre was used. Burning 3,600 pounds per day, 9 per cent. nitre was required, and with 3,000 pounds, 8 per cent. As the cubic capacity of the set was 107,200 cubic feet, the following represents the pounds sulphur, per cent. nitre, and cubic feet per pound sulphur.

Pounds sulphur.	Per cent. nitre.		Cubic ft. per pound sulphur.
4,000	10	=	26.8
3,600	9	=	29.8
3,000	8	=	35.7

Several years after this the capacity was nearly doubled by the addition of two more chambers, the whole being run in one set, with a

Gay Lussac and Glover—still burning brimstone. The total number of cubic feet was now 202,600, the towers and connecting pipes not being included. Sulphur charged was about 10,500 pounds a day, per cent. nitre from 3 to $3\frac{1}{2}$.

The following gives the totals of four weeks running (28 days), being a fair illustration of the workings of the chambers when in good condition:

Total sulphur burned	295,265	pounds.
" nitre potted	10,005	"
No. of blowups of nitrous acid run through the Glover	325	"

Dividing these figures by 28, we get as the daily average:

Sulphur burned	10,545	pounds.
Nitre potted	357	"
Blowups of nitrous vitriol through the Glover	11·61	"

The test of this nitrous vitriol was made with permanganate, using 5 cc. of solution, containing 15·8 grams $KMnO_4$ per litre, (= $\frac{1}{2}$ normal.)

The nitrous vitriol was run into this from a graduated pipette, the volume required varying from 1·2 cc. to 1.5 cc. Adding up the total tests made in the above 28 days, I find that as a daily average 1·352 cc. nitrous vitriol exactly decolorized the 5 cc. of permanganate. It results from this that 100 pounds nitrous vitriol contains N_2O_3, equivalent to 4·62 pounds of chemically pure nitrate of soda. 11·61 blowups of this went daily through the Glover, each blowup delivering 2,334 pounds 1·7 specific gravity acid. Hence, total nitrous vitriol = 27,097 pounds at 4·62 per cent. = 1,252 pounds pure $Na\,NO_3$ = 1,291 commercial 97 per cent. nitrate.*

Hence the chambers were charged with nitre as follows:

From Glover	1,291	pounds.
" nitre pots	357	"
Total	1,648	"

This 1,648 pounds, nitre = 15.62 per cent. of the weight of the sulphur (10,545), and the chamber capacity (202,600 cubic feet) = 19.2 cubic feet per pound sulphur.

* The acid after it had passed through the Glover was tested to see if it had any action on the $KMnO_4$, with practically negative results, proving that the acid had been completely denitrated, and was free from foreign reducing substances.

Combining this with results from old set of chambers, we have:

Sulphur burned.	Per cent. nitre.	Cubic ft. per pound sulphur.
4,000	10	26.8
3,600	9	29.8
3,000	8	35.7
10,545	15.62	19.2

The above shows the proportion of the two variables; nitre and cubic feet per pound sulphur, under widely different circumstances. For the nitre varied from 8 to over $15\frac{1}{2}$ per cent., and the cubic feet from 35·7 to 19·2, the increase of one being proportionate to the decrease of the other.

This being the case the product obtained by multiplying the two together should be nearly a constant quantity, as follows:

$$
\begin{aligned}
10 \times 26{\cdot}8 &= 268 \\
9 \times 29{\cdot}8 &= 268 \\
8 \times 35{\cdot}7 &= 285 \\
15{\cdot}62 \times 19{\cdot}2 &= 300 \\
\text{Mean.} &= 280
\end{aligned}
$$

To give an illustration of the meaning of figure 280: a chamber with 280 cubic feet capacity per pound sulphur would require 1 per cent. nitre, one with 140 cubic feet would require 2 per cent., with 28 cubic feet 10 per cent., with 14 cubic feet 20 per cent., and so on.

It is not to be expected that any formula based upon such changeable *data* as are furnished by the gases of an acid chamber, will give absolutely unvarying results. Changes of the seasons of the barometer, of temperature, of the direction of the wind, of the steam pressure, and from a hundred local sources cause the result to vary within certain limits. Although the figures given above are derived only from this one particular set of chambers, and although it would be very interesting to have corroborative proof from other experiences, nevertheless it must be remembered that the above trials extended over a number of years, and were made under very widely different circumstances. They were made when the capacity was only about 100,000 cubic feet, and again when it was double this; when the chambers were running without towers, and later when both Gay Lussac and Glover were present. Therefore, since in all these cases the resulting figures were closely accordant, they may be accepted by any manufacturer as a check upon the working of his chambers.

The chamber capacity in cubic feet, multiplied by the per cent. nitre

used, and divided by the number of pounds of sulphur burned daily should give a result not far from 280, and all the better if it approaches to 300. If the result falls considerably below the former figure, it is a pretty safe indication towards a low yield in acid, and a consequent loss in dollars and cents.

THE GEOLOGY OF PHILADELPHIA.

By Professor H. Carvill Lewis.

[A lecture delivered before the Franklin Institute, January 12, 1882.]

The formations upon which the city of Philadelphia is built may be divided into two great classes—the superficial formations and the underlying rock strata. The former of these, much the most recent of the two, are for the most part closely connected with the "Great Ice Age" which formed the subject of the lecture given one week ago. A description was then given of the ice-covered area of Pennsylvania, and of the numerous phenomena of glacial action which pertain to that region. The extent and the causes of glaciation were discussed, and an attempt made to arrive at some idea of its age. The great glacier which covered the whole northeastern portion of our continent, and which, as a great sea of ice, flowed in a continuous stream across Labrador, the Laurentian highlands of Canada, the Adirondacks, the Catskills and the Alleghanies, was proved to have finally stopped within sixty miles of our city. At the extreme edge of the glacier it heaped up a terminal moraine, composed of rock fragments brought from more northern regions, which moraine was shown to stretch in a continuous line completely across our State.

Directing our attention now to the rivers which cut through the moraine, it will immediately be evident that, at the time of the melting and retreat of the great glacier, these rivers must have been swollen to great dimensions by the floods which then rushed down them. They constituted the drainage courses for the waters of the melting glacier. Our spring freshets are nothing in comparison to the mighty torrents into which these rivers must have then been converted. These torrents brought down immense masses of loose material made by the glacier, while at the same time they tore up and carried down stream loose rocks all along their beds. When at last the flood subsided there remained as witnesses of its extent the clays, the gravel and

the cobblestones which we are about to study in detail. Among the rivers which brought down these deposits were the Delaware, the East branch of the Susquehanna and the Alleghany.

On the other hand, as may be seen by reference to the map of the moraine, the Schuylkill and the west branch of the Susquehanna did not issue from glaciers, their source being south of the moraine. It is now evident, therefore, why there are no drift deposits in the valleys of the last-named rivers, while on the other hand such deposits are of great extent in the river valleys first named.

A small portion of the superficial deposits of that part of the Delaware which lies between Trenton and the sea is due to marine or estuarine action, being more ancient than the deposits of glacial times.

In entering upon an examination of the geological formations of any place, the first step is the construction of a geological map. This we may proceed to do in our city as follows:

THE UPLAND TERRACE.

1. A traveler going from the city upon the Germantown Railroad will notice in the cuttings for new streets between Tenth and Broad streets, and in the railroad cut at New York Junction, numerous exposures of red or yellow gravel, often overlaid by clay. The brickyards in the vicinity of Nicetown expose large beds of brick-clay, containing occasional well-rounded boulders and pebbles. The land so far has been comparatively level, and no rocks have been seen. Just before reaching Wayne Junction, rocks rise upon both sides of the road, the clay and gravel disappear, and a rolling wooded country is entered. A thin covering of light micaceous soil, containing no pebbles or boulders, covers the gneissic rocks from here to Chestnut Hill. There is a great contrast between the two regions.

2. On the Pennsylvania Railroad it will be noticed that, soon after leaving the depot, gravel covers the rocks along the Schuylkill, and as the railroad turns back from the river, a plateau of clay follows. The Centennial grounds lie upon this clay, and boulders are frequent, a good section being exposed near the bridge at Belmont avenue. Upon reaching Fifty-seventh street, opposite Belmont and George's Hill, the hill is entered by a cut, the rocks come to the surface, and the drift is no more seen.

3. Again, on the North Pennsylvania Railroad gravels first appear,

then, on higher ground, clay, and soon after passing Green Lane Station, the rocky uplands, free from drift.

4. So, too, on the West Chester Railroad, gravels and clays cover the ground up to the base of the hill on which Swarthmore College stands.

5. On the other hand, the New York division of the Pennsylvania Railroad and the Philadelphia, Wilmington and Baltimore Railroad, which run parallel with the Delaware river, do not rise out of the region of drift.

Now, connecting by a line the four points mentioned, it will be found to represent a long straight hill, 200 feet or more in height, having a northeast and southwest trend, parallel to the river, and lying at a mean distance from it of about four miles. The speaker has traced it, through Bucks, Philadelphia and Delaware counties, into the State of Delaware, and finds that it uniformly defines the western boundary of the drift. This hill is easily recognized, where uncrossed by creeks, being remarkably straight and of uniform height. It forms the limit of tide-water, and is recognized where it crosses streams by the occurrence of rapids or falls. Being the first hill of importance west of the Delaware, it often commands a fine view, and is a favorite site for residences. The geographical position of this ancient terrace may be more exactly defined in the vicinity of Philadelphia as the hill which crosses Second street pike near Foxchase, and, crossing Tacony creek farther south, runs nearly parallel with it as far as Crescentville; which crosses Green lane and New Second street road near the place of Mr. J. L. Fisher; crosses the North Pennsylvania Railroad above Olney road, and the York road below the Jewish Hospital; which crosses Germantown avenue at the railroad bridge (being here called Negley's Hill), and running along the railroad to beyond Wayne Station, passes back of the Germantown Cricket Ground, past Old Oaks Cemetery, to Falls of Schuylkill. Thence, passing Chamouni, Belmont and George's Hill, it crosses the Pennsylvania Railroad near Hestonville, and Haverford road at Haddington; passes back of the Burd Orphan Asylum into Delaware county, and runs north of Kelleyville, Clifton and Morton to Swarthmore College, and thence, past Village Green, into Delaware.

North of Philadelphia, this hill may be followed through Bucks county, past Somerton, to the Neshaminy creek, when it crosses the Bound Brook Railroad, and then bends back to form the hill back of

Yardleyville. This hill, which is approximately parallel not only to the river, but also to the shore of the Atlantic Ocean and to the line of strike of the Cretaceous formations of New Jersey, forms, as we have seen, the main dividing line between the ancient and the modern formations.

The speaker has called it for convenience the *Upland Terrace.* The strike of the gneiss forming it corresponds closely with the trend of the terrace itself. A boulder-bearing clay rests upon its southeastern slope, at a uniform elevation of 150—180 feet above mean ocean level. While it is true that, as will appear hereafter, there are patches of an ancient gravel on high points back of it, the Upland Terrace nevertheless remains as the most important geological feature in southeastern Pennsylvania.

Between the Upland Terrace and the Delaware, clays and gravels cover the rocks in a continuous sheet except where eroded away in the neighborhood of streams. The amount of their erosion is in some respects a measure of the age of the surface formations. These formations in the vicinity of Philadelphia have undergone very different amounts of erosion, the amount of such erosion increasing as we recede from the Delaware; and this fact offers evidence that the deposits are of different ages; those lying farthest from the river and highest in elevation being the most ancient, and those which are close to the river, which have undergone but little erosion, being the most modern of our surface formations. Examples of erosion of the Philadelphia gravel may be well seen on the Philadelphia and West Chester Railroad, which crosses a number of creeks and runs nearly parallel to the terrace for several miles. As each creek is approached the drift disappears and rocks come to the surface. So, on the Schuylkill, no gravel is seen on the river drive in the East Park, but, upon going back from the river and rising 100 feet above it, as far as the East Park Reservoir, gravel appears abundantly. Yet, on the same river, nearer the Delaware, a newer gravel, made of different materials, not only forms its banks but underlies it.

RECENT ALLUVIUM.

The most recent of all the surface deposits is the stiff bluish clay which covers the low ground in the southern part of the city. The Richmond meadows and the flats of Moyamensing, Greenwich and Tinicum are covered by this deposit. It is bounded by a low ter-

race, which is from 10 to 15 feet above tide. This terrace, up to which the river often comes in times of flood, crosses South Broad street diagonally below Moyamensing avenue, and, crossing the Delaware extension of the Pennsylvania Railroad, near Penrose Ferry road, winds around Point Breeze Park back towards the Gas Works, and, passing below Suffolk Park, crosses into Delaware county. Sometimes, as in Tinicum, certain islands of older gravel, rise out of the mud-flats. The blue clay of this formation is too stiff to be useful for brickmaking. Blackened fragments of twigs, roots and leaves are frequent in it, and it is said that trunks of the white cedar abound in it in some places. There is here an indication that these beds are sinking and that, as on the Atlantic coast, the water is encroaching. Frequently a good peat covers the clay. Artesian well records show that this blue mud at Frankford is 24 feet deep. Generally it is much shallower, and is underlaid by a sand, the formation next older.

THE TRENTON GRAVEL.

A light sand and gravel, free from clay, underlies the blue clay just mentioned, and extends considerably farther back from the river. It is composed principally of a sharp micaceous sand, which, when below water-level, becomes a "quicksand." Gravel lies below the sand. Unlike all the other gravels, it contains but few pebbles of white quartz, and is of a dark gray color. Its pebbles are made exclusively of the rocks forming the upper valley of the river. Their shape is also very characteristic. The pebbles of the older gravels are oval or egg-shaped, but these are for the most part flat. This flat shape is characteristic of all true river gravels. At several places along the Delaware, gold has been obtained from this gravel. The absence of clay in any of its layers indicates the action of swiftly running water. Data obtained from artesian wells have shown that this formation has a depth on Delaware avenue of about 50 feet, and that it extends up to about Third and Market streets. On Smith's Island and on the bar in the river opposite Cooper's Point it is 100 feet deep, lying upon rock. It therefore underlies the river, filling up its ancient channel. On Richmond street some very large boulders are seen lying upon the sand. Bridesburg and the Lazaretto are built upon it, the latter formerly an island surrounded by bog clay. The sand is used for building purposes. It is bounded by a terrace, which rises some 25 feet above mean tide, and is capped by the red gravel

and brick clay about to be described, while rocks are frequently exposed at its base. The Chester branch of the Reading Railroad lies below this terrace, and the present line of the Philadelphia, Wilmington and Baltimore Railroad is above it. This sandy river gravel forms islands in the blue mud. It forms a level plain, and lies in a channel-cut, the older formations to rock. It evidently formed the ancient river bed.

This last and newest of all the gravels is one which at Philadelphia seems to be of little importance. It lies close along the river, and, rising a few feet above it, extends but a short distance back from the river bank. Yet, from its great development farther up the river, and more especially from the fact that in this formation, and in this formation only, have traces of ancient man been discovered, it acquires great interest, and we are tempted to inquire more fully into its boundaries, its age and its origin.

On tracing this gravel up the river, it is found that, from Philadelphia to the Neshaminy Creek, its boundary is generally between the line of the Pennsylvania Railroad and the Delaware. From this point the bounding terrace trends directly towards Morrisville and away from the present river. Thus, at Bristol, the gravel and its overlying sand extends two miles back from the river, and is bounded by a well-marked hill, upon which lie older gravels and brick-clays. These and the Tertiary gravels extend nearly seven miles inland. At Tullytown our formation extends two and a-half miles back, and at the canal shows the following succession of strata: (1) sandy loam, 1 foot; (2) fine gray "moulding-sand," $2\frac{1}{2}$ feet; (3) sharp "bar-sand," 1 foot; (4) clean gray river gravel of unknown depth. In other openings near here the gravel is so full of boulders that these are dug in large quantities and sent to Philadelphia for "cobblestones." Near Wheatsheaf Station, close to the railroad, an opening which has exposed a section of the gravel nearly half a mile in length, exhibits well the general features of the formation. The pebbles, of characteristic shape and color, are made of gray Triassic argillite, slate, red shale, sandstone, conglomerate, and various other rocks found farther up the valley, while large and often sharp boulders of red shale and other materials frequently occur. The whole formation has a very fresh appearance when compared with older gravels. Near Turkey Hill a large smooth boulder, five feet in diameter, lies upon the sand.

Upon reaching Trenton, we find an immense outspread of the gravel,

and numerous fine exposures of it, both on the river bank and in the long cuts made by the Pennsylvania Railroad. The formation may therefore be designated for convenience the "*Trenton Gravel.*"

Trenton is in a position where naturally the largest amount of a river gravel would be deposited, and where its best exposures would be exhibited. It is at the point where a long, narrow valley with precipitous banks and continuous downward slope, opens out into a wide alluvial plain at a lower level. It is here that the rocky floor of the river suddenly descends to ocean level and even sinks below it, forming the limit of tidewater. Thus any drift material which the flooded river swept down in its channel would here, upon meeting tide-water, be in great part deposited. Large boulders which had been rolled down the inclined floor of the upper valley would here stop in their course, and all be heaped up with the coarser gravel by the more slowly flowing water except such few as cakes of floating ice could carry oceanward. On the other hand the finer gravel and sand would be deposited farther down the river.

This is precisely what occurs at Trenton. The material, which at Philadelphia is generally fine, grows coarser as the river is ascended, until at Trenton we find often immense boulders imbedded at all angles in the gravel. Moreover, the river has here cut entirely through the gravel down to the rock, exposing at one place a cliff of gravel 50 feet high. At Philadelphia, on the other hand, as we have seen, the river still flows on the top of the gravel. This fact may also be accounted for. Having heaped up a mass of detritus in the old river channel as an obstruction at the mouth of the gorge, the river, so soon as its volume diminished, would immediately begin wearing away a new channel for itself down to ocean level. This would be readily accomplished through the loose material, and would be stopped only when rock was reached. On the other hand, that gravel which had been deposited at places farther down the river where its bottom was below ocean level, would remain un-eroded or nearly so. When the river had attained the level of the ocean there would be no occasion to cut a deep channel, and it would therefore flow on top of the gravel which it had deposited.

The fact of the river having cut through the gravel at Trenton, while at Philadelphia it flows upon it, is due to the configuration of the rock floor of the river, which at Trenton rises above ocean level, and at Philadelphia lies nearly 100 feet below it.

At the time of the flood which deposited the Trenton gravel, the lower part of Philadelphia, the whole of Bristol and Tullytown, and almost all of Trenton were submerged. That the climate was then cold is indicated not only by the suggestion that there were then probably very large masses of boulder-bearing ice floating in the river, but also by the fact that, as stated by Dr. C. C. Abbott, bones of Arctic animals (walrus, reindeer, mastodon), often rounded by attrition, have been found in this gravel. The boulders resting upon the sand overlying the gravel suggests the grounding of large ice-cakes derived from some mass of ice large enough to be called a glacier.

It is difficult to imagine an origin for such a flood as we have described other than the melting of a glacier. This flood was not an inroad from the sea, but it came down the valley. Terraces of the same gravel may be traced above Trenton up the valley of the Delaware into the glaciated region above Belvidere. At Stroudsburg it is probably the same gravel which forms the well-marked terraces about the town, and there is every proof that the age of this formation is that immediately following the final retreat of the great glacier.

THE PHILADELPHIA BRICK CLAY.

The built-up portion of the city stands upon an extensive deposit of brick clay and gravel, sections of which are exposed in every cutting. The brick clay invariably overlies the gravel, and will therefore be first described. By far the finest exposures of brick clay are those on either side of Long lane, in the "Neck." The clay here is very compact, free from sand and gravel, and is often 15 feet or more in depth. Loam lies above it, and is mixed with it for brick-making. Well-rounded boulders of Potsdam, Medina, Trias, etc., are frequent. The whole lies upon some 20 feet of stratified gravel. It is a much finer and deeper clay than that of the northern part of the city, as at Nicetown. It is interesting to note that while the clay which is farthest from the Upland Terrace and lowest in elevation is purest and deepest, on the other hand that near the terrace, and more than 100 feet above the river, is both shallow and sandy. It suggests that the former was deposited in deep water and the latter near the shore. At the base of the terrace the clay is but two or three feet deep. The boulders of the Nicetown clay are similar to those of the Neck clay, except in the fact that in the latter there are numerous rounded and sharp fragments of triassic red shale, while in the former boulders of that material are

very scarce. The boulders of both clays are invariably derived from a northern source. No shells or organic remains have as yet been noticed in this formation, and it is therefore inferred both that the water was fresh and that it had a temperature too low to support life.

In the collection of boulders from this clay made by Mr. Eli K. Price, and deposited in the University grounds, many of the rocks which occur along the Delaware from Trenton to beyond the Water Gap are represented. Some of them are derived from the Terminal Moraine. The lecturer has been able to trace almost all of them to their source. He has also traced the boundaries of this boulder bearing clay up to the glaciated region, and finds that it uniformly rises to a fixed limit of 150 to 180 feet above the river. Where the valley is wide, as at Philadelphia and Trenton, the clay is pure and fit for brick-making, but in narrow and steep portions of the valley the current has been too swift for the deposition of clay and it is represented by occasional, stranded, waterworn boulders. This clay rests against the upland terrace from Trenton to Philadelphia, at an elevation of 150 feet. On the Lehigh river, a tributary of the upper Delaware, where the bed of the river is more than 200 feet higher than at Philadelphia, the clay rises 180 feet above the river. That this was an epoch of submergence is indicated by the elevation of the deposit. While the underlying gravel was deposited by a rushing flood, it was not until quieter conditions had prevailed that clay could be formed. It is probable that this clay may be assigned to a period when the land stood 150 feet or more below its present level, and when the cold waters from the melting glacier bore ice rafts which dropped their boulders.

These boulders are often of large size. Thus in Philadelphia there are smooth boulders of Silurian rocks between 4 and 5 feet long, at an altitude of a 100 feet above the river; and on the Lehigh above the Gap, we have found a boulder six feet long, elevated 150 feet above the river at that place. In the vicinity of Bethlehem, thirty miles below the Terminal Moraine, the boulders in the clay sometimes show glacial striæ. It hardly admits of doubt that these boulders were borne by large cakes of floating ice derived from the base of the melting glacier. Finally, it is of interest to find that the clay which cements the unstratified "*till*," the "ground Moraine" which covers the glaciated region to the north, is of a character so similar to the Philadelphia brick clay, that there is a strong probability that the

latter was derived, in great part, directly from the grinding base of the glacier. The Philadelphia brick clay becomes more and more stony as we proceed northward, until in valleys at the base of the Terminal Moraine of the glacier its stones are almost as numerous as those of the true glacial till. Deposits of this boulder-bearing brick clay have more than once been confounded with glacial moraines. The latter, however, as is well known, may be distinguished by the abundance of angular and ice-scratched boulders and by the absence of stratification.

THE RED GRAVEL.

Beneath the clay, and often unconformable with it, is the Philadelphia red gravel. It is a clayey gravel which packs well and is much used on roads, and whose red color is caused by the ferruginous clay in which the pebbles are imbedded. The pebbles are composed of all kinds of rock and are not flattened as are those in the river gravel. The predominant material is white quartz, but pebbles of all other materials, as conglomerate, sandstone, fossiliferous hornstone, flint, red shale, etc., are numerous. Stratification is observed in almost every section exposed. Good sections of gravel are seen near the University of Pennsylvania. It has here an elevation of about 50 feet, and comes to the surface of the ground with but a very slight covering of clay.

The clay almost always lies in the form of crests and hollows upon the gravel. Beautiful examples of wave motion may be seen at Twenty-eighth Street and Columbia Avenue, at Tenth and Tioga, at Fifteenth and Clearfield Streets, in Fairmount Park, at the Penna. Railroad cuttings near Belmont Avenue, and in many other places. In each of these we have apparently the action of a rushing flood of water upon the gravel. Often the clay lies in a kind of pot-hole in the gravel, and a concentric structure of clay and pebbles can be seen. At Twenty-eighth Street and Columbia Avenue six well-marked waves of gravel and clay may be seen, the clay always filling the hollows between the crests of gravel. Along the line of contact between clay and gravel there are alternate streaks of fine and coarse gravel.

A very beautiful example of water action is exposed at Fifteenth and Clearfield Streets, in a cut about one hundred feet in length.

Another point to be noticed in the section near the University is the stratification of the gravel, and its division into layers of three different colors,—red, black and yellow. It is instructive to note that this division is by no means a local one, but exists along a line of about

equal elevation (60 to 80 feet above ocean level), in widely separated parts of the city. While the colors are of course due simply to different states of oxidation of the iron, the fact that they mark continuous deposits through long distances, indicates a uniformity in the condition of deposition which could be due only to the presence of a large body of water.

The gravel rests, not upon a hard floor of rock, as is usual with the drift in more northern States, but upon a completely decomposed gneiss. This is universally the case in every section examined in the vicinity of Philadelphia.

The lower part of the gravel often consists of a sharp, stratified, micaceous sand, made up of the materials of the decomposed gneiss. Exposures in the East Park and along the line of the North Pennsylvania Railroad illustrate this fact. It is evident, therefore, that the gneiss was decomposed before the deposition of the gravel, and that water, not ice, was the agent of that deposition. The idea that a glacier once overrode the site of Philadelphia and deposited gravels and boulders has recently been urged by a Philadelphia geologist* but is not sustained by the observed facts. In fact there is no trace of glacial action in Pennsylvania, anywhere south of the terminal moraine, notwithstanding all statements to the contrary hitherto made by other geologists.

The red gravel was deposited by a flood of the ancient Delaware, at a time when it flowed at a level over 100 feet higher than at present. It is closely of the same age as the brick clay, both having been formed during or at the close of the glacial epoch. Many facts go to prove that the red gravel and the brick clay were formed at the time when the glacier began to retreat from its terminal moraine, the ground being then depressed about 180 feet, while the Trenton gravel, which flows in a channel cut through these deposits was formed long afterwards when the last lingering remnants of the glacier were thawed out, and when the land had risen to about its present elevation.†

*Mr. Hall, (Proc. Amer. Philos. Soc.) who concludes "that this belt of drift deposit is no other than a glacial moraine formed by the Schuylkill glacier receding from the site of the city."

† A map was here exhibited of the boundaries of the surface formations of Philadelphia, as traced out by Professor Lewis. He showed that these formations were confined to the river valley, being bounded by the "Upland terrace," and that they appeared on both sides of the river. He showed also that during part of the Glacial Epoch the Schuylkill emptied into the

THE YELLOW GRAVEL.

Nearly the whole of Southern New Jersey and a small adjoining portion of Pennsylvania are covered by a deposit of yellow gravel which has been variously known as quaternary, southern drift, etc. It extends southward all along the Atlantic coast in the region of tide water, rising some two hundred feet above the level of the ocean. It caps the watershed between the Atlantic and the Delaware (elevation 190 feet), and is well exposed in the railroad cuts at Glassboro and other places in New Jersey. This gravel, unlike those so far described, is not confined to the Delaware valley, but occurs all along the Atlantic seaboard in the Southern States. It is therefore of oceanic origin.

It is characterized by small water-worn pebbles, somewhat egg-shaped in form, seldom above an inch in length, usually less, and composed of quartz or quartzite rocks. There are also occasional pebbles of flint, and of fossiliferous hornstone and chert. It contains no large boulders, and has no pebbles of soft or readily decomposable rocks, and its pebbles have nearly all a weather-worn eaten appearance. Still other circumstances, such as the great amount of erosion it has suffered, and the decomposed state of the beds upon which it lies, point to the conclusion that it is an ancient deposit of marine origin, made during a submergence in preglacial times. The glacial drift overlies and is more recent than this yellow gravel. This gravel is of a yellowish color, becoming white when exposed to the weather, and is more sandy than the red gravel. For these reasons it is less esteemed for road making. The Germantown railroad cuts through this gravel at New York junction. The speaker has found here pebbles containing cyathophylloid corals, favosites, a trilobite, etc. The connecting railroad at Ridge avenue station cuts through the same gravel, and here occur *strophomena*, etc. Other fossils have been found below the clay in the East Park and at the Centennial Grounds. Pebbles of triassic red shale, so common in the red gravel, do not occur in this older yellow gravel.

The yellow gravel, which can always be recognized by the fossiliferous pebbles of Niagara limestone, etc., in it, may be studied on Darby

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Delaware at the Falls of Schuylkill, and that the State house steeple would then have been completely submerged. He spoke of the gold, which, in small quantity, disseminated throughout the clay, stating that it has been estimated that $126,000,000 of gold lies underneath the paved part of the city, and many times more within its corporate limits. He also described the process of brick making.

road, near the horse car depot, in the railroad cut at Ridley Park, Delaware county, where corals and other fossils abound, and in many other places in and about the city. It generally occurs near the base of the upland terrace upon a plateau covered by more recent brick clay. It is from this oceanic gravel that most of the pebbles of the red gravel have been derived. The yellow gravel is probably of *newer Pliocene* age.

THE BRYN MAWR GRAVEL.

Upon the summits of some of the highest hills in the gneissic region back of Philadelphia, at a mean distance of about nine miles from the river, and at elevations of from 325 to 450 feet above it, there are isolated patches of an ancient gravel, different from any yet described, to which the speaker has given the provisional name of "The Bryn Mawr Gravel." It can always be recognized by the presence of sharp or partially rounded fragments of a hard, heavy iron sandstone or conglomerate. Such fragments are often covered by a brownish black iron glaze. More than fifteen years ago, the speaker noticed in the soil of the upper part of Germantown, pieces of this conglomerate, unlike any known rock, and it is only of late that its origin has been suspected. It consists of well-rounded pebbles of quartzite or siliceous sandstone cemented by iron into a stone which is often very hard. This conglomerate is found in occasional fragments upon ground over 300 feet high, but is not found in abundance until an elevation of over 400 feet is reached. At these highest points it occurs in a red gravel whose pebbles are identical with those of the conglomerate.

One of such points is near Chestnut Hill, on the city line road at its highest elevation, near Willow Grove road. Here, nearly nine miles from the river and 425 feet above it, is a patch of this gravel and conglomerate, in which sharp fragments of quartzite are numerous, but there are no traces either of triassic red shale, of fossiliferous pebbles, or of rounded pebbles of the underlying gneiss.

A similar tract of this gravel occurs at Bryn Mawr, extending from that place to near Cooperstown. A good section is exposed in the railroad cut below the station. From this locality the formation is named. It is here about 430 feet high, and nine miles from the river. The gravel is ten feet deep, and lies upon a steeply-dipping gneiss so completely decomposed that it is as soft as clay. Here, as at Chestnut Hill, the gravel lies in an isolated patch upon a hill, distant from any

stream or other eroding agency. The gravel holds sharp fragments of primal rocks, and also the iron conglomerate. As at Germantown, the fields below, to the south, contain occasional fragments of the conglomerate.

Another good exposure of the Bryn Mawr gravel is on a hill crossed by the road leading from Haverford College to Cooperstown. The conglomerate is here in large, sharp fragments, and the gravel shows slight horizontal stratification. On the crest of the hill, some 450 feet high, there is a weather-worn boulder, four feet in diameter, of a soft, coarse, brown sandstone of Bryn Mawr age, apparently in place.

A fourth, precisely similar exposure of gravel with conglomerate, and at about the same elevation, caps the hill back of Media, near the Rosetree.

Without describing any further exposures, it already appears that in these elevated patches of ancient gravel we have the last remnants of a once continuous formation. The very great erosion which has swept away all but these few traces is a sufficient proof of its age. There are no points at all approaching the elevation of these hills, between them and the Atlantic Ocean; and it is at once suggested that these patches are the remnants of an oceanic deposit, possibly of Tertiary age. It is interesting to find that a precisely similar formation caps some of the hills in New Jersey. On top of the hill at Mount Holly, N. J., is an identical conglomerate and gravel, similar in appearance, and composed of the same materials as the formation in Pennsylvania. The conglomerate has the peculiar ferruginous glaze already noticed. It here overlies cretaceous marls and sands.

The Bryn Mawr gravel caps numerous high hills in Delaware county, and in northern Delaware increases largely in extent, covering the gneiss hills in patches several miles in length. At a point two miles northeast of Wilmington it comes within a mile of the river. It is in many places five feet deep and is less eroded than in Pennsylvania. As in Pennsylvania, its pebbles are mostly of sandstone and quartzite, and fragments of iron conglomerate ore abundant. A similar formation occurs upon the heights of Georgetown, D. C., and continues through the southern States in the same relative position. It is probably of Tertiary age, and represents the outliers of portions of the gravelly shore line of certain oceanic deposits which, nearer the Atlantic, are more largely developed, but represented by clays, sands, and such other finer material as would be deposited farther from shore.

This region has been elevated over 400 feet since these deposits were laid down, a fact which may lead to a more precise estimate of their antiquity.

Recapitulating the various surface formations here distinguished as occurring at Philadelphia we have, beginning with the most recent:

Formation.	*Geological Age.*
Recent alluvium.	Modern.
Trenton gravel.	Post-glacial.
Philadelphia brick clay.	Glacial.
Red gravel.	Glacial.
Yellow gravel.	Pre-glacial.
Bryn Mawr gravel.	Tertiary.

In these six deposits is written the ancient history of the Delaware valley. If we read the record aright, they tell us that, long ago, before man was created, when strange mammals roamed abroad, and when all southern New Jersey lay deep beneath the Atlantic, the waves of the ocean broke upon the hills of Bryn Mawr, Chestnut Hill and Media. At the same time, an inlet from the sea extended over a great part of the Montgomery county limestone valley, depositing clays holding extensive beds of iron ore. This region, then 450 feet lower than now, was afterwards slowly upheaved, and as the waters retreated, the yellow gravel was probably formed. Afterwards, and perhaps in consequence of this rise, the climate grew colder, and glaciers crept down from Greenland and Labrador, forming a huge *mer-de-glace* thousands of feet in thickness, which advanced to within 60 miles of Philadelphia. Again the land descended 175 feet lower than it now is, and again the waters covered the city. This time it was fresh water of icy coldness, bearing great icebergs, which stranded on the shores formed by the hill at Wayne Junction, Belmont, George's Hill, Hestonville, Haddington and Swarthmore. At this time the river Delaware was 10 miles or more in width, nearly 200 feet deep, and, as a roaring flood, deposited the red gravel and left in it the records of its waves. As the flood became more quiet, though still filled with mud derived from the base of the glacier, the brick clays were laid down, the floating ice floes meanwhile dropping their far carried boulders all over our city.

After many thousands of years, the "Great Ice Age" at length came to a close, the land rose to about its present level or somewhat higher, the waters retreated, and finally, as sudden elevations of tem-

perature thawed the glaciers still remaining in the head waters of the Delaware, there came those last great floods which deposited the "Trenton gravel." The Delaware, then so wide as to submerge most of Trenton, all of Bristol, and the river front of Philadelphia nearly up to the State house, was again filled with floating icebergs. The walrus played in its waters, while the reindeer and the mastodon roamed on its banks. Man also then first appeared With habits most probably like those of the Esquimaux, living in most primitive ways, he hunted and fished on the banks of the swollen Delaware, and occasionally dropped into the water his rude stone implements, long afterward to be found to tell the story of their makers.

Finally, the land began the sinking which is now in progress, the climate grew warmer, the Red Indian was introduced, and the modern era began.

This, in brief, is the tale told by our clays and gravels, Surely the long despised cobble-stones of our ill-paved streets become more worthy of our respect when we know their story. Still more interesting do they become when we learn that they can tell us of the early history of our own race. They belong to the "Trenton gravel," and we have already spoken of the relation of that formation to the *Antiquity of Man* on the Delaware. It now remains to point out more exactly what that relation is.

(To be continued.)

Production of Sulphur in the Soil of Paris.—Some recent excavations for public works, in Paris, have opened masses of mixed rubbish in which there is an abundance of native sulphur. Its crystallization can be perceived by the naked eye, and the microscope shows that the crystals are octahedral, with the usual forms of natural crystals, sometimes truncated and combined with right prisms. Daubrée attributes the origin of the sulphur to the simultaneous presence of sulphate of lime and organic matters which are associated with it, such as vegetable remains, manure, leather, and fragments of bones. In some places the quantity of sulphur is sufficient to pay for mining. It consists of a breccia of small fragments, incrusted with crystalline sulphur, which helps to cement them together. Crystallized sulphur is also produced between fibres of decayed wood. When the bed was opened it exhaled a powerful odor, resembling that of phosphorus, which was attributed to phosphuretted hydrogen.—*Comptes Rendus.*

KENNEDY'S REMOVABLE-SEAT STEAM VALVE.

At the stated meeting of the Institute held February 21, 1883, the Secretary exhibited and explained for the manufacturers (McCambridge & Co., Philadelphia) the above-named invention, which may be concisely described with the aid of the cuts, as follows:

Fig. 1 represents a circular metallic cage, in the bottom of which the valve seat is cut; this is the removable seat, and constitutes the

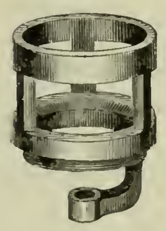


Fig. 1.

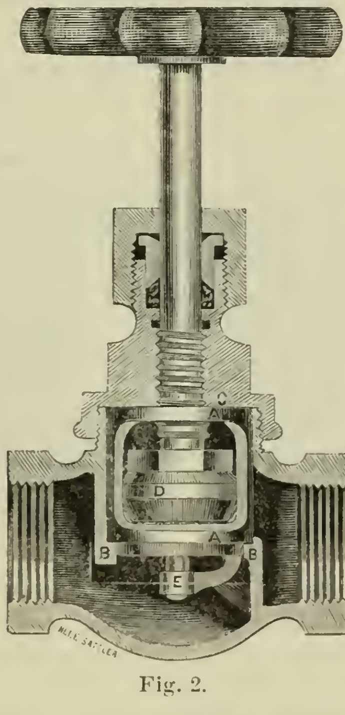


Fig. 2.

principal feature of the improvement. The prong (*E*) extending from the bottom of the cage and seat is a guide through which the stem in disk works; it insures the disk coming squarely upon the seat, and is very convenient for regrinding.

Fig. 2 represents an ordinary steam globe valve, with this modification attached. (*BB*) represents a flat seat cut in the body of the valve upon which the bottom of the cage (*A*) rests; the cage (*A*) is held in this position by means of the cap (*C*), which screws down upon

its top face, holding it as firmly as though it and the body were one casting. The bottom of the cage (A) and the seat in the body (BB), upon which it rests, are true surfaces, which, when pressed tightly together, as described above, form a tight joint, and as the cage always remains stationary after being put in place there is consequently no wear between them, so that when it becomes necessary to take out an old cage, to put in a new one, or regrind the seat in the old one, the seat in the body (BB), upon which the cage rests, will be found quite unworn; care should be taken, however, to see that this seat is entirely free from scale or other matter (which may have fallen upon it during the removal of the old seat), before dropping the cage upon it. The disk (D) is detachable from the stem, and must be duplicated each time a new seat is put in. The makers furnish duplicate seats and disk which they guarantee to be interchangeable, and to fit accurately any valve the size for which they are made.

Some of the advantages claimed for this valve are the following: That the valve seat and disk may be removed at will, and either reground or duplicated; that the valve is virtually a new one each time the seat and disk are renewed; and that the body of the valve need never be removed from pipes to repair or renew seat; all of which save time, and add materially to the usefulness of the valve.

Descartes and the Barometer.—Prof. L. Nourisson has read to the French Academy a memoir upon the relations between Pascal and Descartes. Twelve years before Torricelli performed his experiment, Descartes wrote as follows: "Air is heavy; it may be compared to a huge mass of wool, which surrounds the earth; the weight of this wool, pressing upon the surface of mercury in a cup, and not acting upon the surface of the mercury in the tube, prevents the mercurial column from descending. This weight is limited, and it does not prevent the descent until the weight of the column is less than its own. In order to detach the mercury from the ceiling of the tube, a greater force is required than that which is represented by the weight of the wool, or, in other words, of the air. The force which depresses the column of mercury is its own weight; the weight of the column which is elevated above the level of the cup is, therefore, equal to the weight of the air upon a portion of the surface of the cup equivalent to the surface of the column in the tube."—*Comptes Rendus.* C.

THE HALL TYPE-WRITER.

[From the Report of the Secretary, March 21, 1883.]

The machine herewith illustrated by a perspective view and two sections, represents a new and much simplified form of type-writer, invented by Thomas Hall, and made by the Hall Type-Writer Company of New York. The machine is very compact, and the mechanism by which its work is performed is quite ingenious.

The machine is enclosed in a box 17 inches long, 7 inches wide, and 3 inches deep, and as the total weight is only 5½ pounds, it will be seen that it is very portable. The perspective view gives a fair idea of the apparatus, when standing on a table, with the box opened, and

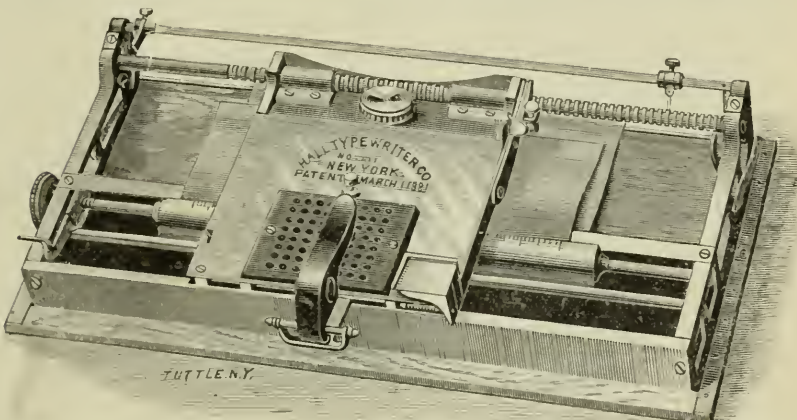


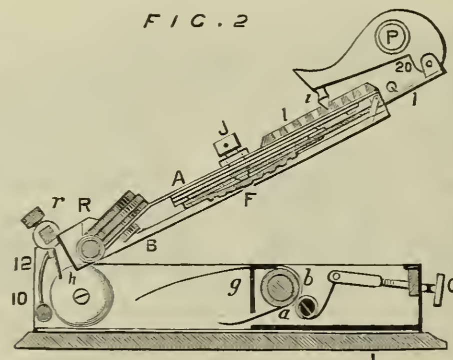
Fig. 1.

ready for work. The mechanism is carried upon a light bar frame, nickel-plated, hinged to the bottom of the box in front, and provided with pivotted bars at the back, the lower ends of which fit into serrated catches attached to the bottom of the box, so that the frame can be set at any convenient angle for working.

There are two distinct series of motions to be provided for: those affecting the paper, and those required for operating the type. The paper receives no lateral movement, that being provided for in the type mechanism, but it has to be fed upwards at the end of each full or broken line of printing, through a distance suitable to preserve the distinctness of the lines. Between the end bars of the frames and

towards the front of the apparatus is a spindle, enlarged for the greater part of its length so as to form a roller (b) Fig. 2, which is covered with india-rubber, as shown. On the left-hand side of the frame this spindle terminates with a small milled wheel, by which the roller can be turned at will. Immediately in front of the roller, and embracing it for its whole length, and for about one-third of its circumference, is the curved plate B, made very thin, nickel-plated, and graduated along its upper edge for a purpose to be presently described. The lower edge of this curved plate is fastened to the bar a, Fig. 2, parallel to and placed below the centre of the roller. The paper, which may be of any width up to 14 inches, and of any length, is held between the rubber face of the roller and the curved plate; the latter can be adjusted so as to increase or diminish the grip. This is effected by a light

FIG. 2



spring connected with the bar a, and the stud and set-screw C; by lifting this latter a, the bar can be turned slightly round, and the plate B, moved from the roller. As soon as the lower edge of the sheet of paper is introduced between the curved plates and the roller, turning the milled disk W brings it forward into the position shown in the drawings, and printing may be commenced in any part of the sheet. We may assume, however, that it is intended to begin at the top left-hand corner, in the usual manner. To do this the sheet is fed forward by turning the milled disk and roller, till the desired margin is left at the top. As soon as one line has been printed, or whenever it is desired to commence a new line, by turning the head W a new surface of the paper is presented. It is obvious, however, that unless care were taken to turn the roller each time through a fixed distance,

the space would be irregular, and the appearance of the work untidy. To secure a uniform feed and therefore regular spacing, the lever L at the left-hand side of the machine is introduced. By pressing the thumb-piece at the end of L upwards, the roller a is caused to move through a certain distance, by the action of a spring coiled round the spindle of the roller, and connected to the lever L, and the angle frame g (Figs. 1 and 2). Stops above and below limit the travel of this lever. For spaces of varying widths which may be occasionally required, the milled disk W might be easily graduated, and set by means of a fixed pointer.

We have now to consider the more complex mechanism for producing the printed characters on the paper. As the latter does not move laterally, it is evident that the form must have such a motion, that after one letter has been printed, the type must travel from left to right through a determined space, so as to bring the letters successively over an unprinted part of the sheet. As every one knows, some letters occupy more space than others; thus I i occupy less room than M m, and the difference is greater in small, or "lower case" letters, than in the capitals. In the Hall machine the space for each letter is equal, for the eye very rapidly becomes accustomed to the apparent irregular spacing, and the simplicity of the machine is very greatly increased. Having impressed one letter, then, on the paper, the type traverses towards the right through a fixed distance—one-tenth or one-twelfth of an inch—and so on till the end of the line is reached. The way in which this is accomplished should now be described. The whole of the printing mechanism is carried by the carriage A (Fig. 2) hinged at the top to the rod R, and resting at the bottom on the front bar of the frame. The perspective view shows this arrangement clearly, and Fig. 2 indicates the mechanism; in this figure the carriage A is shown raised in position to show the printing. The rod R is held fast in suitable brackets at the top of the frame. For the whole of its length, excepting a short distance on the left, this rod is cut out in circumferential grooves so as to form a rack. The broad hinges attaching the plate A slide freely over the rod, but are very carefully fitted, so that there is no shaking, which would interfere with the regularity of the printing. Near the top of the carriage and in the centre of its width is a small circular box, with teeth around its circumference, and containing a coiled spring; the teeth engage in the grooves of the rod R, and tend to move the carriage. Suppose that the latter has traveled

along bar to the right-hand extremity, then by pressing a lever, the carriage can be pushed back by hand to the left-hand end; but this operation coils up the spring in the box, and secures a sufficient motive power to traverse the carriage from left to right for the whole length of the machine. In this way the forward travel is obtained, but it is evident that the movement must not only be intermittent, but must be normally limited to one tooth of the rack on the bar *R*, equal to the width of the spaces between the printed letters. The device by which this is effected is simple and ingenious; it is indicated in the perspective view, but requires a separate diagram to make it quite intelligible. On the right-hand side of the carriage A is a flat lever pivotted to and near the top of the plate by a pin, the head of which projects. Pinned to this lever, and lying close beside it, are two other shorter levers, one of which is a spring always tending to open. At their upper ends both of these levers have a semicircular recess, the diameter of which corresponds with that of the grooves in the rack bar *R*. The end of the long lever first mentioned has also a similar semicircular recess, which in its normal position is just clear of the lower half of the bar *R*, the two short levers pinned to it engaging in the upper half of one of the grooves; in this position the carriage *A* is held firmly. If the long lever is depressed by touching the finger-plate *S*, the upper end of the lever is raised, and the semicircular recess engages in one of the grooves on the under side of *R*, which locks the carriage; at the same time the two short levers pinned to it, are raised clear of the groove. Now the projecting stud on which the long lever turns, passes through a hole in the outer short lever which, as already said, is formed of a spring. As these levers are pinned to the long lever, it follows that the depression of the latter raises the short levers, but the instant that the spring lever is clear of the bar *R*, it flies open, against the stop *A* (Fig. 1). The coiled spring, however, in the box on the carriage cannot force the latter forward because it is locked by the end of the long lever engaging in the bar *R*. As soon as the lever is released, however, its end falls clear of the bar, and the coiled spring then forces the plate forward, the two short upper levers falling into the next groove, and locking the carriage again. The stop against which the spring lever presses, and just referred to (*A*, Fig. 1), is adjustable, so that the carriage can travel through one or two spaces, or not travel at all. The long lever, with the finger plate *S*, is used to produce the spaces between the words; precisely the same result is obtained by depressing the top plate of the

carriage, to which the system of levers is attached; this forms the spaces between the letters. In this way the carriage travels intermittently from left to right of the machine, either across the whole width of the paper, or for any distance that may be desired. In order to return the plate to the left-hand side, all that is necessary is to press a thumb-piece on the inner short lever, and a similar thumb-piece fast on carriage; this raises the upper ends of the short levers free of the grooved bar, and the carriage is then slid backward, the movement winding up the coiled spring; a new line may then be commenced, care being taken to feed the paper up through one space by lifting the lever *L*.

The printing mechanism is all contained in the carriage *A*. It consists of an upper and lower plate about three-eighths of an inch apart;

1	2	3	4	5	6	7	8	9
(	&	;	"	—	?	%	$	)
K	B	F	G	N	I	A	S	Q
J	C	D	O	E	H	T	W	V
X	M	Y	L	.	R	U	P	Z
k	b	f	g	n	i	a	s	q
j	c	d	o	e	h	t	w	v
x	m	y	l	,	r	u	p	z

the lower one is rigid, resting on the front bar of the frame, and connected to the rod *R* by brackets, on which it is free to turn, while the upper one is also hinged to the rod, as shown in the perspective view, and is held up from the bottom plate by levers fixed to a small shaft on the front of the upper plate, which is acted on by a spiral spring just strong enough to lift the plate, two spring latches fixed to the lower plate keeping it, however, in position. To the top of the upper plate is screwed a rectangular piece of ebonite, 3 inches long by $2\frac{1}{4}$ inches wide, in which are pierced seventy-two tapered holes, each hole corresponding to a type character. There is also a stud *J* about the middle of the plate and projecting through it on both sides. The printing characters are all raised in relief on a thin elastic plate of vulcanized rubber about 3 inches square, and stiffened around the edges by a light brass frame. The arrangement of the letters is such

that those most frequently used may come most easily to hand. The above diagram shows the extent and arrangement of these characters.

A variety of these forms, which can be fixed with very little delay, are manufactured, so that any class of type may be employed suitable for any language. They are attached to an articulated frame, shown in Fig. 3, which is a plan of the underside of the top plate A. This frame, which constitutes a parallel motion, has its fixed points at 16, 16, and is free to move in any direction with equal facility, and in such a way as to bring a character exactly beneath the stud *J* in the plate *A*. Fastened to the frame carried by the parallel motion is the key *P*, hinged, as shown, by a pin to the plate *1* (Fig. 2), going off to the frame just alluded to, and to which the form is attached. At the end

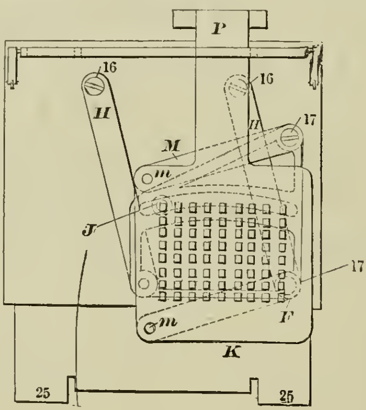


Fig. 3.

of the key *P* is a nipple *i*, which fits the holes in the ebonite plates, but does not go to the bottom of them. If, then, this nipple be placed in the hole belonging to the letter, F, for example, the movement necessary to bring the key to this hole, also by means of the parallel motion, brings the letter F on the india-rubber form, immediately under the stud *J*, and immediately over a small square hole in the lower plate of the carriage *A*, through which the paper is exposed. Then, if the key *P* be depressed, the upper plate of the carriage *A* is is also depressed, and the letter F is brought into contact with the paper. The upper surface of the bottom plate of the carriage *A* is covered with an inking pad, and it follows that when the top plate is depressed all the characters in the form are brought in contact with the inking pad, except F, the ink from which is transferred to the paper.

The same action of depressing the plate sets in action the intermittent feed already described, and when the plate rises, the carriage A moves to the right, the space of one letter, and a blank piece of paper is again exposed through the small square opening in the bottom plate of the carriage. When the end of a word is reached the operator depresses the spacing lever by touching the finger-plate S, and the carriage traverses the necessary distance. The bed on which the paper rests to receive the impression is formed of the angle bar g (Fig. 2.), which runs between the end frames immediately behind the roller b.

Two more points connected with this extremely ingenious machine remain to be noticed; the first refers to the device for regulating the length of the lines. Above and behind the rack bar R, is a square grduating rod running from end to end of the type-writer. On this slide two stops that can be set in any position by set screws. The right-hand stop is provided with a tail rigid in one direction, but free laterally. On the back of the carriage A is a finger, and when this comes in contact with the tail just mentioned, the latter rises, giving the square bar a partial turn on its axis, until the contact ceases by the passage of the carriage, when the bar actuated by a spring returns to its normal position, and in doing so stikes a bell, and thus notifies that the end of the line is reached. The second point refers to the means provided for going back to any place on the line to make a correction. The square bar just alluded to is graduated, and the curved plate clipping the paper is also graduated to correspond, so that if the pointer on the top left-hand side of the carriage be set at the same division as that opposite any letter to be corrected, the form is brought back to the exact spot.

The machine permits the work to be inspected at any time by lifting the carriage A without letting go of the handle P; a great variety of characters can be employed, and the use of only one key renders the manipulations easily and quickly acquired, for a speed of thirty to fifty words a minute. The workmanship, as is absolutely necessary for mechanism of this class, is excellent.

Sire's Pendulum.—M. Sire has presented to the French Academy a modification of Foucault's pendulum, which accurately exhibits the laws of displacement in whatever latitude the experiment may be tried.—*Comptes Rendus.* C.

Book Notices

The Materials of Engineering. In three parts. Part I. Non-Metallic Materials; Stones, Timbers, Fuels, Lubricants, etc., by Robert H. Thurston, A. M., C. E., etc., etc. New York, John Wiley & Sons, 15 Astor Place, 1883.

That eminent mechanic, James Naysmith, defined *Engineering* as "Common Sense applied to Materials," and although the definition is broad rather than accurately descriptive, it suggests in a forcible manner the necessity which requires of the *Engineer* a thorough knowledge of materials, their nature and capabilities. In the practice of his profession he operates on materials, and the laws of physical science are the tools with which he works. He is ever on the alert to add to his knowledge of the characteristics of these materials, and eagerly grasps each new fact that is presented to his notice. In the book now before us, the first volume of the series, Prof. Thurston presents carefully arranged and thoroughly indexed a vast amount of useful information concerning the various non-metallic substances with which the engineer may have to do, and incorporates in his pages the latest investigations of many observers.

Chapters I, II, and III, give in a compact form a general description of all the chief varieties of building materials comprised under the heads—stones, cements, and timber—and states the principal localities from which they are each obtained, their physical peculiarities, the uses to which they are each especially adapted, the proper method of preparation, etc., etc. Very full tables are given of strengths of masonry, brickwork, and the different kinds of wood used in construction. The various kinds of masonry are described and illustrated, together with many cements and mortars. The strength of timber is treated at length, considerable space devoted to the various methods that have been adopted for preserving wood, and the subject concluded by a valuable table giving at a glance the special adaptations of the various kinds to the uses of the carpenter, the ship builder, and the millwright; and also a classification of special properties showing the woods grouped under such heads as stiffness and elasticity, toughness and strength, etc.

The many varieties of Fuels are treated in Chapter IV, the physical and chemical characteristics described, relative efficiency of various

fuels and furnaces discussed, and the general principles governing economy in combustion set forth.

Chapter V contains in an abridged form the gist of Prof. Thurston's treatise on *Friction and Lubrication.*

Chapter VI covers a collection of useful facts concerning such topics as Leather Belting, Paper, India Rubber, etc., and the remainder of the book is made up of a brief description of the metric system, followed by a number of tables for the comparison of metric with U. S. standard weights and measures. The "Centimetre—Gramme Second" system of Units, is also described and a short table of four figure logarithms is given.

If this book is justly open to any criticism, it is perhaps that these complete metric tables, etc., which occupy nearly one-sixth of the entire number of pages, cannot be strictly included under "Materials of Engineering," and in fact would be more serviceable in an engineer's "pocket-book," or in a separate binding rather than as an appendix to such a volume as the present. It may also be questioned whether the practice, rigidly adhered to, of giving all dimensions in terms of the metric scale as well as in English equivalents, does not increase the bulk of the volume without giving any commensurate advantage, especially as convenient conversion tables are now so common. These are, however, merely matters of individual preference, and we are none the less indebted to the author for another valuable addition to the Engineer's library.

Modification of Electrodynamic Energy by Terrestrial Motion.—J. Frölich finds by experiment that the mutual influence of two currents is not fully expressed by Grassmann's law, but that it is also somewhat dependent upon the hour of the day. He also finds that many of the electrodynamic laws which have been hitherto accepted involve a theoretical assumption that the conductors and the free electricity are referred to the earth in a hypothetical state of absolute rest. Clausius, in a late pulication, has recognized the importance of Frölich's views, and Rowland's investigations require a consideration of the earth's motion for a satisfactory interpretation—*Wied. Annal.* C.

[The relations of electricity and magnetism to cosmical motion were discussed by Chase, in the proceedings and transactions of the American Philosophical Society for 1864.]

Microscopic Inscription of Physiological Movements.—M. Marey has invented an instrument which enables him to make an exact record of the phenomena of circulation, respiration, and muscular and nervous actions. By employing a fine steel point and a thin layer of lampblack, movements which do not exceed one-tenth of a millimetre ($\frac{1}{250}$ in.) are magnified to great dimensions. The apparatus can easily be carried in the pocket.—*Comptes Rendus.* C.

Elasticity and Electric Conductivity of Coal.—W. Becty reports a series of experiments upon some cylindrical sticks of coal prepared by Carré, estimating their modulus of elasticity by determining the note which is produced by rubbing them longitudinally with rosined fingers. All the observations showed an increase of conductivity with increase of temperature. He does not think that coal, whether compressed or prepared from gas coke, is so homogeneous as Siemens supposes, but its texture is sufficiently uniform to furnish conclusive evidence of the relations which he has pointed out.—*Ann. der Phys. und Chem.* C.

Thermal Theory of the Galvanic Current.—J. L. Hoosweg finds that there is always an evident decomposition, when the thermo-electric equivalent of electrolysis exceeds the electromotive force of the battery. He deduces from his experiments the following conclusions: 1. Every manifestation of electricity is a consequence of the disturbed thermal currents, at the point of contact between two heterogeneous bodies. 2. Electricity is propagated either through conduction or dielectric radiation. 3. Bodies may be divided into dielectrics and adielectrics. In the first the conductivity increases, in the second it diminishes, with an increase of temperature. 4. An electrolyte is a decomposible dielectric. 5. In every closed circuit, of which a portion is dielectric, the sum of the potential differences is either greater or less than zero. 6. The galvanic current arises at the expense of the temperature at one point of contact and produces an increase of temperature at the other. 7. The electrolytes in the circuit are always decomposed. Hence arise new differences of the potential, which may diminish the previous sum or even reduce it to zero, through chemical polarization. 8. The change of temperature is estimated by the galvanic heating, the production of warmth at the points of contact, and the chemical heating. These changes lead to thermal polarization. —*Ann. der Phys. und Chem.* C.

Cause of Weakness in the St. Gothard Tunnel.—Investigations have been made of the cause of weakness in the parts of the St. Gothard tunnel where the vaults were crushed, and it is thought that the accident must be attributed to the action of damp air upon the schists and gneiss, and to the decomposition which resulted therefrom; the presence of anhydrous sulphate of lime, or karstenite, was also an important agency; its transformation into gypsum is followed by a disaggregation which renders the rock incapable of sustaining its pressure. Other hypotheses have been framed, but M. Loustan considers this as the most plausible.—*C. R. de la Soc. des Ingin. Civ.*

Dust, Mist, and Clouds.—Mr. Aitken draws the following conclusions from an extensive series of experiments: "Whenever vapor condenses in the atmosphere, the condensation is always made on a solid nucleus, which is furnished by particles of dust. Without dust there would be neither mists nor clouds, and the super-saturated air would transform every object upon the earth's surface into a condenser upon which it would deposit its excess of water. Whenever the breath becomes visible in a cold atmosphere it demonstrates the impure and dusty condition of the air. The foam of the sea, meteoric matter, and fires are fertile sources of the dust and impurity."—*Les Mondes.* C.

South American Woods.—M. Thanneur describes some varieties of South American wood which seem likely to become valuable for engineering purposes. The yandubay is exceedingly hard and very durable. The couroupay is also very hard and very rich in tannin. It bears some resemblance to the quebracho, which is perhaps the most interesting of all and the most used. It is very abundant in Brazil and La Plata. Its diameter varies within the same limits as that of the oak, but the trunk is shorter. It is used for railway sleepers, telegraphic poles, piles, etc. It is very durable, especially when well seasoned. It is much heavier than water, its specific gravity varying between 1·203 and 1·333. Its color is reddish, like mahogany, but it becomes darker in time. On account of its hardness it is difficult to work, and it cannot be readily cut with an axe. It has been introduced into France on account of its richness in tannin. A large portion of the Brazilian leather is tanned by the sawdust of quebracho, but the leather is rather brittle. A mixture composed of one-third of powdered quebracho and two-thirds of ordinary tan gives very good results.—*Ann. des Ponts et Chauss.* C.

Mariotte's Law.—Amagat's various experiments upon the compressibility of gases, show that the belief that a gas continues to vary from Mariotte's law by becoming less compressible as the temperature continues to be increased, is not correct. If hydrogen were cooled sufficiently it would finally be compressed more than the law indicates; on raising the temperature the variation from the law would first vanish and then become negative; but this variation, instead of continuing to increase negatively, would attain a maximum and then begin to approach unity.—*Ann. de Chim. et de Phys.* C.

Mean Temperatures of the Northern and Southern Hemispheres.—Hennessy called attention, more than twenty years ago, to the superiority of water over the other materials of the earth's surface, for the absorption and diffusion of solar heat. His conclusions were diametrically opposed to those which had been previously adopted, but they have gradually commanded the increasing support of observers. W. Henel has therefore published the conclusion, that the difference of temperature between the two hemispheres is very small, and that the southern hemisphere, which has the larger mass of water, also has the higher temperature. M. Hann has given a summary of observations, in the *Comptes Rendus* of the Vienna Academy, and he concludes that 15·2° (59·4F.) is the temperature of the two hemispheres.—*Comptes Rendus*, xcv, 471. C.

Influence of Minute Mixtures.—The presence of $\frac{1}{30000}$ of a pound of antimony in a pound of melted lead increases the rapidity with which the lead oxidizes and burns. Lead which contains more than $\frac{1}{14000}$ of its weight of copper, is unfit for the manufacture of white lead. Gold with an alloy of $\frac{1}{2000}$ of lead is extremely brittle. Copper with $\frac{1}{2}$ per cent. of iron has only 40 per cent. of the electric conductivity of pure copper. Nickel was regarded as a metal which could be neither rolled, hammered nor welded, until it was found that the addition of $\frac{1}{1000}$ of magnesium, or of $\frac{3}{1000}$ of phosphorus, makes it malleable. Some varieties of cast steel are exceedingly brittle, but the addition of $\frac{1}{12}$ of one per cent. of magnesium makes them malleable. At the Paris Exposition of 1878, a great difference was found in the toughness of sheets which were made of Swedish puddled iron. The only difference which chemical analysis showed was, that the good plates contained $\frac{20}{100000}$, and the bad $\frac{21}{100000}$, of phosphorus.—*Der Techinker.* C.

Newton's Rings.—Sohncke and Wangerin have repeated and extended their observations upon Newton's rings, with results which confirm their early views with regard to the slight eccentricity of the rings. If the microscope is so placed as to give the sharpest possible definition to any portion of a dark ring, in order to see another ring, or even another part of the same ring, it is not sufficient to move the microscope in a parallel plane, but it must be elevated upon one side and depressed upon the other.—*Ann. der Phys. und Chem.* C.

Treatment of Copper in the Bessemer Converter.—P. Manhès, of Lyons, has successfully applied the Bessemer process to the treatment of copper ores. M. Gruner states that the method has reduced the metallurgical labor from six or eight operations to three, and although he does not anticipate so radical a revolution as in the production of steel, he does not hesitate to predict a brilliant future. In France, especially, where fuel is dear, the process will utilize ores which have hitherto been worthless. The progress is the more remarkable, because the metallurgy of copper had remained completely stationary for the last fifty years.—*Bull. de la Soc. d'Encour.* Sept. 1882. C.

Tones Produced by Intermittent Radiation.—W. C. Röntgen was induced, by Bell's experiments with the photophone, to employ an apparatus which he had long used in his physical lectures for showing the effects of intermittent radiation in gases. He used the lime light as a source of heat. The rays were concentrated by lenses upon a notched disk of pasteboard, which could be rapidly rotated about a horizontal axis. An absorption apparatus was placed behind the notches, with a short glass tube, of one centimetre diameter, over which was placed a wide caoutchouc tube that led to the ear of the observer. The rays penetrated into the absorption apparatus when openings in the disk came in front of the rock salt plate, and were interrupted by the unnotched parts of the disk. With air, hydrogen, or oxygen, he was unable to obtain any tones; but with illuminating gas and with ammonia distinct tones were heard, somewhat like the whistling of a moderate wind. The pitch varied with the velocity of rotation and the tone vanished only when the rotation became very rapid.—*Wied. Annal.* C.

New Analysis of Tobacco Smoke.—G. Le Bon, and G. Noel, have sent to the French Academy three vials, containing products which they have succeeded in extracting from tobacco smoke. They are: 1, prussic acid; 2, an alkaloid of an agreeable odor, but dangerous to breathe, and as poisonous as nicotine, since $\frac{1}{20}$ of a drop destroys animal life; 3, aromatic principles, which are as yet undetermined, but which contribute, with the alkaloid, to give the smoke its perfume. The alkaloid appears to be identical with collidine, which has been observed in the distillation of many organic substances, but its physiological and poisonous properties have been hitherto unknown.—*Comptes Rendus.* C.

Relation between the Major and Minor modes in Music.—F. Ricard has been experimenting with a key board of equal temperament, and finds that inversion changes the mode from major to minor, and *vice versa.* M. Corun, without adopting Ricard's views upon the constitution of musical scales, thinks that this curious inversion is worthy of study, and that it may throw some light upon the obscure questions relative to the interpretation of major and minor melodies.—*Comptes Rendus.*

[The "Orginnette" furnishes great facilities for experimenting on inversion. Some of the results are very curious, and if they are carefully investigated, they may lead to important scientific conclusions.] C.

Selenium as a Regulator of Heat.—P. Germain proposes to use the various degrees of resistance which selenium opposes to the passage of electricity at different temperatures and under different rays of the spectrum, to the regulation of the temperature, in muffles for enameling painted glass or porcelain. He uses a thermo-electric battery of thirty elements, which receives the heat directly from the muffle. The opposite pole is connected with the wall of a porous vessel, full of water, which maintains a sensibly constant temperature. The thermo-electric current increases in potential proportionally to the elevation of the temperature in the muffle. The selenium is brought into the circuit, but it remains comparatively unaffected until the muffle has reached the proper luminous temperature, when it allows the current to pass and to give a signal by means of a bell.—*Comptes Rendus.* C.

To WHOM IT MAY CONCERN:

At a stated meeting of the Franklin Institute, held Wednesday, March 21st, it was

Resolved, That the President be authorized and requested to appoint, as early as practicable, a Committee to examine the several forms of apparatus used for projections upon the screen of illustrations of all kinds, for lectures, etc.; that the said Committee be requested to invite the co-operation of those interested in the manufacture and use of these instruments, to the end that they may be induced to offer their instruments for competitive tests in comparison with others; that the Committee have the permission to make use of the lecture-room of the Institute for their purpose on any evening when it is not engaged; and that they be requested to prepare a report embodying the results of their investigations, together with such recommendations respecting the construction and use of such instruments as they may deem proper to make.

The Committee appointed under this resolution have directed me to send a notice to the various parties known to be interested in the sale and exhibition of projecting apparatus, asking them to furnish this Committee with specimens of their instruments for comparative tests.

If you wish an examination made of your instruments, please notify.

Yours respectfully,

CHAS. M. CRESSON, M.D., *Chairman of Committee.*

No. 417 Walnut street, Philadelphia, April 5, 1883.

LIST OF BOOKS ADDED TO THE LIBRARY DURING JANUARY, FEBRUARY AND MARCH, 1883.

Academie Royale des Sciences, etc., de Belgiques. Annuaire, 1883. Presented by the Academy.

Adjutant-General of Pennsylvania. Annual report for 1882. Harrisburg, 1883. Presented by James W. Latta.

Allnutt, H. Wood Pavements. London.

Anderson, W. Manufacture of Gunpowder at Ishapore Mills in Bengal. London, 1862.

André, G. G. Rock Blasting. London, 1878.

Annales des Ponts et Chaussées. Personnel, 1883. Paris. Presented by the Publication Office.

Archæology and Ethnology, American. Fifteenth annual report of the Trustees of Peabody Museum. No. 2. Vol. 3. Cambridge, 1882. Presented by the Museum.

American Railway Master Mechanics Association. Report of proceedings of Fifth Annual Convention. Cincinnati, 1882.
Presented by the Association.

Army Register. Official; for January, 1883. Washington.
Presented by the Adjutant-General.

Astronomical and Meteorological Observations made during the year 1878. Washington, Government, 1882.
Presented by the U. S. Naval Observatory.

Aveling, Thos. Road Locomotives. London, 1878.

Bayley, Thos. Pocket-Book for Chemists. London, 1881.

Beaumont, W. W. Thrashing Machines. London, 1881.

Bell, A. G. Telephone. London, 1878.

Bergen, W. C. Marine Engineer. North Shields, 1882.

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Brevets D'Invention. Catalogues, Sept., 1881, to Feb., 1882. Paris.
Presented by the Ministre of Agriculture, Commerce, etc.

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Britton, T. A. Origin, Progress, etc., of Dry Rot in Timber. London, 1875.

Bureau of Education. Circulars of Information, Nos. 1 and 2. Washington, 1882. Presented by the Bureau.

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Presented by the Bureau.

Bureau of Education. Instruction in Moral and Civil Government. Washington, 1882. Presented by the Bureau.

Bureau of Education. Natural Science in Secondary Schools. Washington, 1882. Presented by the Bureau.

Bureau of Education. Pedagogic Congress in Spain. National. Washington, 1882. Presented by the Bureau.

Calvert, J. Silver Country of the Vazeers in Kulu. London, 1873.

Car-Builders' Association. Report of Proceedings of 16th Annual Convention. Philadelphia, 1882. Presented by the Association.

Christopher, S. Cleaning and Scouring. London, 1877.

Codrington, Thos. Maintenance of Macadamized Roads. London, 1879.

Colonial History of the State of New Jersey. Documents relating to the. Edited by Wm. R. Whitehead. Vol. 6. 1738-1747.
Presented by the Historical Society of New Jersey. Newark.

Cornwall, H. B. Manual of Blowpipe Analysis. New York, 1882.

Darwin C. The Origin of Species by Means of Natural Selection. New York, 1883.

Dictionnaire des Jardiniers. 8 Vols. Paris. Guillot. 1785.
Presented by the late A. I. Brasier, through his sister, Miss Brasier.

Documents relating to the History and Settlement of Towns along the Hudson and Mohawk rivers, from 1630 to 1684. By B. Fernow. Albany, 1881.
Presented by the Regents of the University of the State of New York.

Donaldson, Wm. Art of Constructing Oblique Arches. London, 1867.

Dowson, J. E. and A. Tramways. London, 1875.

Dunbar, J. Practical Papermaker. Leith, 1881.

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Franklin Institute.

Hall of the Institute, April 18, 1883.

The stated meeting of the Institute was held this evening at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

There were present 120 members and 28 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held April 11th, 14 persons had been elected to membership.

He also reported, by instruction, that at the same meeting the Board had adopted the following resolution: *Resolved*, "That the Committee on Exhibition be enlarged, and that the Committee be instructed to take measures to raise an adequate guarantee fund to protect the interests of the Franklin Institute in the contemplated Electrical Exhibition."

The special committee on the "Prevention of Fires in Theatres," presented majority and minority reports which were accepted, and referred to the Committee on Publication.

Mr. C. J. H. Woodbury, of Boston, then read a paper on a "Portable Electric Testing Apparatus," having for its object, to afford a convenient and reliable method of frequently testing the insulation of electric lighting circuits. Mr. Woodbury's paper has been referred to the Committee on Publication.

Mr. Wm. F. Goodwin followed with a paper on the "Goodwin-Roberts Locomotive," in which the special features of the new engine were shown with the aid of lantern views, by comparison with others of improved construction. Mr. Goodwin, claimed in his engine, to have overcome the difficulties raised by Mr. Wolf, at the previous meeting, in his remarks on Mr. Le Van's paper.

Mr. Hugo Bilgram, by request, thereupon described and exhibited in operation upon a lathe, a screw-cutting attachment, invented by Mr. A. Nacke, of Philadelphia. This device automatically releases the jaws of the screw-cutting attachment as soon as the screw has been cut, thereby greatly reducing the time required for cutting screws.

The Secretary's report included among others, a description of the following inventions:

The Continental Underground Cable Company's system of laying underground electric cables, consisting of a series of semi-circular pockets or troughs of sheet metal, contained in an arched chamber of any required size, the foundation and walls of which are made of bricks pressed from a plastic substance described as being strong, hard, and a good insulating material. The cables are laid in the troughs above named, being drawn through or removed by means of a carrier with a rope or chain, which may be run to and fro in the bottom of

the chamber by any convenient motive power applied to a truck running on rails, on which the carrier is mounted.

There was also exhibited and described, John H. Miller's mechanical movement for converting reciprocating into rotary motion, without the intervention of a crank. The same inventor's improvement in cranks was shown, and consists in combining with the usual crank and the fly-wheel connected thereto, a guiding crank, or link attached to a shaft of its own, for the purpose of guiding the pitman, and also in interposing a link between the main crank and connecting rod; the alleged object of the inventor being to give a more uniform motion to the engine to which it is applied.

E. Andrews, of Williamsport, Pa., exhibited several saws, showing a new method of fastening saw blades in handles. The blade has the hand-hole cut in it, and the handle is thereby strengthened by the steel in the butt of the blade; furthermore, the workman gets the advantage of the full stroke of a blade without drawing the arm too far back.

Mr. Oswald McAllister, of Philadelphia, exhibited a Positive Section Liner, for draughtsmen, which was claimed to possess several advantages over others for section lining and shading cylinders. A metal triangular scale, exhibited by Mr. McAllister, was also shown. They are made of brass tubing with a dull, nickel-plated finish.

Under new business, Mr. Robt. Grimshaw offered the following resolution viz: *Resolved*, That papers intended to be read before the Institute shall be printed before reading, and copies of the same placed at the disposal of members, before the meeting, in order to afford opportunity for intelligent discussion. On motion of Mr. Eldridge, seconded by Mr. Grimshaw, the resolution was referred to the joint consideration of the Committee on Meetings and Publication, with the request that they report to the Institute at an early day, some feasible plan for accomplishing the object named in the resolution.

The Secretary called attention of the meeting to the recent death of Dr. B. Howard Rand, for many years an active member of, and professor in, the Institute, and moved that a committee be appointed to prepare a suitable memorial. The motion was approved without a dissenting voice, and the President appointed Messrs. Chas. Bullock and Dr. Chas. M. Cresson to prepare the same.

Adjourned. WILLIAM H. WAHL, *Secretary.*

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PORTABLE ELECTRIC TESTING APPARATUS.

By C. J. H. WOODBURY, OF BOSTON, MASS.

[Read before the Franklin Institute, April 18, 1883.]

The use of electricity for lighting purposes has introduced a new element in the matter of testing such systems. Hitherto the sole object in testing telephone, telegraph and other signal lines was confined to purposes connected with the operation or repair of the apparatus.

Electric faults in the telegraph never injured person or property. Contact with telephone lines never robbed a fire department of its right arm by destroying the fire alarm boxes. There is no instance of these weak currents ever setting fires or causing severe personal injuries like those which have been traced to electric lighting currents.

The difficulties connected with the introduction of the electric light have been inseparable with the use of a new form of energy, for the currents have been so much greater than those hitherto used that their application was virtually a new science. Twenty years after illuminating gas was known, the architect of the House of Commons specified that no woodwork should approach within six inches of a gas pipe.

Whenever an electric lighting current has been diverted from the system, it has generally given unwelcome evidence of its energy. Such occurrences, considered as an accidental loss of energy, are comparable

to the bursting of a boiler or the yielding of a dam; but there is no chance of such extensive injuries to life and property from any mishaps resulting from the use of electric-lighting apparatus.

Wherever the use of a large amount of power is involved, the safety is dependent upon the facility with which the whole is held under control, whether it be the head of water against the water-wheel, the steam in the boiler, or the electricity in the circuit. The experience with the electric light is showing that these currents are more easily controlled than other forms of energy, as far as any elements of danger are concerned.

It is not necessary at this time to recount any of the fires caused by electric lighting, but I am not aware of a single fire of this nature which, in the light of present knowledge upon the subject, is not to be considered as a preventable fire. With proper and *continual* attention to insulation, construction of lamps and of switches, and in the incandescent system also the proper size of conducting wires and *closed* safety catches, there can be so little opportunity for fire from electric lights that, under these conditions, it forms the safest method of illumination.

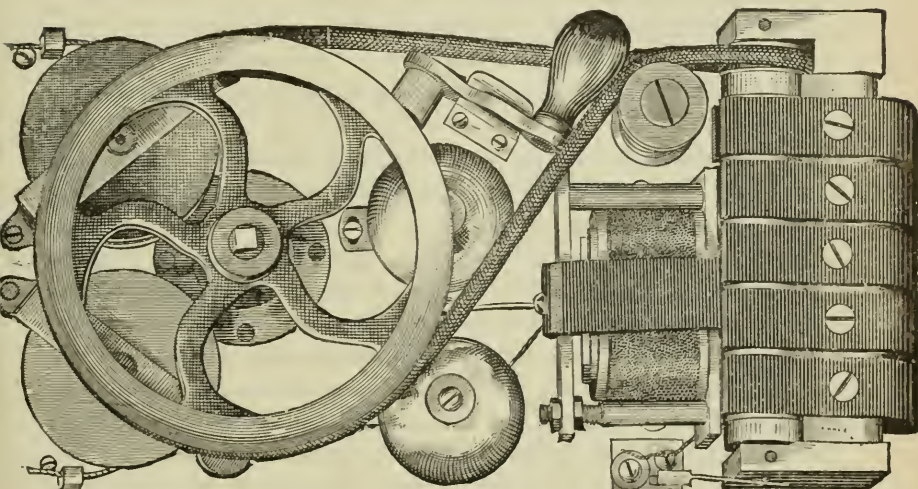
Most of the fires and other difficulties with electric lighting apparatus have been caused by the diversion of the current from the system at distant points, each leading to the earth, and very few accidents due to a conductor making a cross between two adjacent wires. Two contacts are required in order to form the complete circuit necessary to establish an electric current. If a single conductor leads to the earth, only a second one is necessary to divert a portion of the current from the system to the earth, the relative quantities of the current seeking the two paths being inversely proportional to their electrical resistances of the conductors.

Such a diversion of the electricity causes first the commercial loss of electricity. If the contacts are of a nature to diminish the resistance of the circuit, then there is great liability of injury to the armature or commutator in most dynamo machines. The fires have been produced where the electricity met with a conductor of sufficiently high resistance to convert the electricity into heat whose temperature is high enough to burn any combustible substance.

The instances usually occurred on a circuit where one ground connection already existed, and a stream of water leaking during storms, or from washing floors, running over the wires and to the earth formed a

good conductor, which was soon removed, as the electricity dissociated the water, and then an arc was formed as the current strove to maintain itself. Pure rain water is a very poor conductor of electricity, but, in trickling over plaster or whitewash, it takes enough lime or salt into solution to increase its conductivity many times. In some instances, the water connected two wires of diffenent potential. We see the same action when the current is let on an arc-lighting system. When the carbons touch, there is little resistance, and would be no light if the feeding apparatus was not arranged so as to draw the carbons apart and thus present the resistance of the space of the distance between the two carbons.

In the early application of electric-lighting apparatus, ground return



circuits were used as in other electrical circuits, but there were so many difficulties that it was abandoned and metallic circuits are now universally used. I believe Professor Edwin J. Houston, of Philadelphia, was the first one to indicate the dangers of using electric-lighting circuits with ground returns.

If an electric-lighting plant is well constructed and installed in a proper manner, there is no certainty that it will remain in a satisfactory condition on account of the numerous changes, blunders, and accidents to which it is subjected. It is important that each circuit should be provided with some apparatus for the purpose of making frequent tests of the insulation of the whole system. The most precise method

is to use a galvanometer, with a rheostat and battery, but this involves delicate and expensive apparatus, which cannot be used by any one except an electrician; while the weight and bulk of galvanometer, rheostat and ten cells of battery renders it impracticable for portable use.

The above engraving shows a portable instrument for the purpose of electric testing, made from my designs by Charles Williams, Jr., of Boston.

It consists of a Siemens' armature in the field of a battery of five permanent magnets. There is no commutator and the alternating current passes through the coils of a polarized electro magnet which vibrates a striker between two gong bells whenever the circuit is electrically complete.

The armature is revolved from a driving-wheel by means of a quarter-turn belt which passes around an adjustable guide-pulley, whose position can be changed so as to give any desired tension to the belt.

At the end of the case are two reels, each of which contain steel tapes thirty feet in length, forming flexible conductors which are provided with spring clamps at their ends.

The driving-wheel and the reels are turned by means of a crank which fits with square dowels, like a clock key, and when not in use is held by a spring clip as shown in the engraving.

The armature is wound with six thousand feet of No. 40 wire, and measures one inch in diameter, by three inches in length. The whole is contained in a hard rubber case, an inch and a quarter thick, four inches wide, and eight inches long, and weighs three pounds.

The bell will ring through an external resistance of seven thousand ohms, when the crank is being turned, about two hundred times a minute. When the crank is turned more rapidly, the bells can be made to ring through a greater resistance; the limit being about ten thousand ohms, when the crank is revolved as rapidly as one is able to turn.

As a basis of comparison between the limits of this instrument and other methods commonly used in testing, I made some experiments with a vibrating bell (called a jingler) and a compass galvanometer of low resistance.

The resistance of the coils on the electro-magnet of the vibrating bell was two ohms; and with one cell of Leclanché battery, the bell

would ring through a resistance of ten ohms. With a cell of bichromate of potash battery, the bell would ring through a resistance of twenty ohms.

The compass galvanometer was one of those used for testing circuits, the resistance of the coils being eighteen-hundredths of an ohm. The diameter of the graduated circle around the needle was one and a quarter inches, and ten degrees was about the smallest deflection which could be noted under ordinary circumstances. With one cell of Leclanché battery, the needle of the galvanometer would deflect ten degrees through a resistance of seventy ohms. With a cell of bichromate of potash battery, it would make a similar deflection through a resistance of one hundred ohms. More delicate results could have been obtained with galvanometers of higher resistance, but care was taken to use the exact kind of galvanometer made and sold for such purposes.

In comparison with this, my testing magneto will operate through a resistance three hundred and fifty times as great as the vibrating bell with bichromate of potash battery, and seventy times that of the compass galvanometer with the same battery; when a Leclanché cell is used, the ratio is doubled.

These quantities represent the relative delicacy of operation between the vibrating bell and the portable galvanometer with battery as described, and my testing magneto, which requires neither battery nor coils of conducting wires, being complete within itself.

One of the armatures was provided with a commutator, and the following measurements taken with the resistance of the armature amounting to four hundred ohms as the only resistance in the circuit:

Revolutions of crank per minute.	Electro motive force in volts.	Current in amperes.
60	2·00	·0050
120	3·96	·0099
180	6·04	·0151
240	7·96	·0199

The whole efficiency of the testing apparatus depends upon its ability to detect any ground which could, under any circumstances, become an element of danger. The resistance of the

arc-lighting circuits (cold) is very variable, owing to the irregular resistance between the tips of the carbons.

A number of measurements of long arc-lighting circuits show that one and a half ohms to a lamp is a fair estimate for the external circuit, as the connections are usually made. This, on a forty light Brush circuit, would be sixty ohms, and when the bell of the testing magneto can ring through a resistance of seven thousand ohms, it is able to indicate a possible escape of six-sevenths of one per cent. of the current, which, in the Brush system, amounts to nine-hundredths of an ampere or about four and half times the quantity generated by the testing magneto, an amount of energy to small to cause any damage whatsoever.

The same method applied to other circuits show still smaller results, as the resistance of a Brush forty-light circuit is greater than that of the circuit from any other dynamo.

With the low resistances used in incandescent lighting systems, the limit of measurement is still greater. In a one hundred light Edison incandescent plant, this tester would detect a leakage of less than one twenty-fifth of one per cent. of the current used in the whole circuit, or, in this instance, it would show a leakage of one twenty-fifth of the current required for a single sixteen candle-power Edison lamp, which would amount to twice the amount of current generated by the testing magneto.

The method of using the instrument to test for ground connections is to fasten one of the spring clamps to a conductor leading to the earth, such as the stop-cock to a gas pipe, or preferably to a water pipe, and the other spring clamp to the lighting system. When resistance of the insulation between the system and the earth is less than seven thousand ohms, the bells will ring.

If the crank is turned slowly, the bells will ring only through less resistances, and by standardizing these testing magnetos by measuring the limits at various speeds by means of a rheostat, they can be used to approximately measure resistances by counting the speed of the crank necessary to ring the bells.

For testing the insulation of arc lamps, if one clamp is attached to one of the binding posts of the lamp, and the other clamp placed in contact with the various parts of the frame while the armature is revolving, the ringing of the bells will indicate imperfect insulation.

Whenever it is desired to test incandescent systems for crosses, this

apparatus can be used for the purpose by disconnecting one of the main conductors from the dynamo and turning every lamp switch on the circuit; if the lamp sockets are not provided with independent switches, then such lamps must be removed. Care must be taken that the resistance box does not close the circuit. Then attach one of the spring clamps of the testing magneto to each main conductor, and a ring will detect the presence of a cross conductor. By switching off the various branches and testing in sections, any fault can be located to that single branch, and the safety boxes furnish a means for further divisions of the circuit.

This apparatus requires no electrical skill for its use, is not affected by time or temperature, and can be used in any position. They have stood the test of over a year's constant use, without accident or deterioration of any nature.

NOTE RELATING TO A PECULIARITY DISTINGUISHING ANNEALED FROM UNANNEALED IRON.*

By Prof. R. H. Thurston.

The writer has had occasion, recently, to study the effect of prolonged stress upon the various materials in common use in the arts, and, among others, upon the finer qualities of iron. The well-known experiment of Vicat, made half a century ago, had never, so far as the writer was aware, been repeated. The extreme importance of the results obtained by him had, apparently, not been realized by either physicists or engineers, and it seemed advisable that the experiment be repeated, and should the results obtained by Vicat be again reached, that the attention of both scientific and practical men should be again called to the subject. The repetition of Vicat's experiment has not only confirmed his conclusion, but has led to the discovery of a new and important, as well as peculiarly interesting, difference in the effect of prolonged stress upon annealed and unannealed iron.

In the autumn of the year 1881, the writer procured two lots of the best Swedish iron wire from Mr. Wm. Hewitt, Vice President of the Trenton Iron and Steel Works, who very kindly had the wire drawn for the purpose. This wire was divided into two parts, one being

* From advance sheets of *Science*.

carefully annealed, the other being left hard-drawn as it came from the blocks. These were tested in the usual way and it was found that the hard wire had about double the strength of the soft. Nine pieces were taken from each reel for test under prolonged static stress and were suspended from hooks, in the study of the writer, attached to springs in order that the effect of jar should not enter into the experiment.

They were then loaded with respectively, in each set, 95, 90, 85, 80, 75, 70, 65, 60, 55 per cent. of the average ultimate strength, as already determined. This was done in November, 1881. Since that date, a number have broken, as follows:

Effect of Prolonged Stress.—Swedish Iron Wire.

Per cent. max. static load.	Time under stress.	
	Hard wire (unannealed).	Soft (annealed).
95	80 days	8 minutes.
90	35 "	5 minutes.
85	17 months, unbroken	1 day.
80	91 days	266 days.
75	Unbroken	17 days.
70	"	455 days.
65	"	455 days.
60	"	Unbroken.
55	"	"

Thus, wire loaded with but 60 per cent. of the breaking load, as usually determined, broke after being subjected to stress for a period of fifteen months when annealed; while hard wire carrying 85 per cent. of the maximum temporary load remains unbroken after seventeen months. It is seen that these results are the same in kind as those obtained by Vicat, and confirm the conclusion that heavily loaded iron, as well as other metals and the woods, are likely to yield ultimately under loads that are sustained for short periods of time without apparent injury. This fact has been amply proven by earlier investigators, as well as by the writer; but the difference, above

observed, between hard and soft iron has, so far as the writer has been able to learn, never, until now, been discovered.

Although the experiments, of which this is the first, are not yet concluded, this discovery, if such it prove, has seemed to be of sufficient importance to justify this note.

AN EXTENSION OF THE THEOREM OF THE VIRIAL AND ITS APPLICATION TO THE KINETIC THEORY OF GASES.

By H. T. Eddy, C. E., Ph. D., University of Cincinnati.

(Concluded from page 348.)

4. Relation of the Molecular Forces to Temperature, Volume and Pressure. Expression for Work done, and the Second Law of Thermo-Dynamics.

The first member of (13) is the mean energy of the progressive molecular motion of a unit of gas; and since heat is known to be energy, this energy is assumed to be part of the sensible heat existing in the gas—the total sensible heat being the total kinetic energy, progressive and rotary and vibratory, existing in the gas.

Let k be the specific heat of the gas at constant volume measured in mechanical units, and let τ be the absolute temperature; *i. e.*, the zero of temperature is a state devoid of kinetic energy; then the statement just made is expressed by the equation

$$\tfrac{1}{2}\,\Sigma_1^n\, m\,(x'^2 + y'^2 + z'^2) = a\,k\,\tau, \tag{26}$$

in which a denotes what fraction of the total heat-energy, $k\tau$, contained in the gas, exists in it in the form of progressive molecular motion. It seems to be pretty well established by experiment that a is very nearly, if not quite, constant for permanent gases; and by permanent gases is meant any gas or vapor above the critical temperature above which it is uncondensable by pressure alone. This definition of permanent gases includes of course imperfect gases having intermolecular attractions of sensible magnitude.

From (26) and (13)

$$a\,k\,\tau = \tfrac{3}{2}\,p\,v + \tfrac{1}{2}\,\Sigma\, r\, R \tag{27}$$

When the last term of (27), which is dependent upon the intermolecular attractions, is so small that it can be neglected, this equation

expresses the empirical law of Gay Lussac for the so-called perfect gases, and it also includes Boyle's law.

But, in order to treat permanent gases, these attractions must not be disregarded. Retaining, then, all the terms, let a variation of state of the gas occur, the relation between the variations in any change of state of the gas will be expressed by the equation

$$a\,k\,d\,\tau = \tfrac{2}{3}\,(p\,d\,v + v\,d\,p) + \tfrac{1}{2}\,\Sigma\,(R\,d\,r + r\,d\,R), \tag{28}$$

which admits of several comparisons with experimental results, which are of considerable importance in enabling us to correctly estimate the effect of the intermolecular attractions. These comparisons will be made later in the paper.

While speaking of their attractions, it should be remarked that were it possible to actually remove all attractions between molecules which themselves occupy an appreciable fraction of the total space in which they move, the effect of their mutual encounters could be considered to be that of a feeble repulsion, for their centres cannot approach within a certain small distance of each other without experiencing an insuperable repulsion; but this effect is better taken into account by regarding the volume v not as that of the total space occupied by the gas, but as the free space remaining after deducting that actually occupied by the molecules themselves. The space so occupied may be taken to be approximately that of the gas when condensed to the liquid state. Our formulæ may then be all rendered more exact by defining v to be this free space.

To obtain the work done during the expansion of a gas, divide (27) by $\frac{3}{2}v$ and multiply by dv.

$$\therefore p\,d\,v + \tfrac{1}{3}\,\Sigma\,r\,R\,\frac{d\,v}{v} = \tfrac{2}{3}\,a\,k\,\tau\,\frac{d\,v}{v}. \tag{29}$$

But v varies as r^3,

$$\therefore v = c'\,r^3, \quad \therefore \frac{d\,v}{v} = \frac{3\,dr}{r}. \tag{30}$$

Substitute in the second term of (29)

$$\therefore p\,d\,v + \Sigma\,R\,d\,r = \tfrac{2}{3}\,a\,k\,\tau\,\frac{d\,v}{v}. \tag{31}$$

The first member of this important equation, which is due to Clausius,* expresses work done, the first term being that done against

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* *Phil. Mag.*, S. 4, vol. 50, p. 195, 1875.

external forces, and the second term that done against the intermolecular attractions.

If the increment of the total work done be denoted by dw, and if, for compactness, we put $d\,v \div v = d$ log. v, (29) becomes

$$d\,w = \tfrac{2}{3}\,a\,k\,\tau\,d \text{ log. } v. \tag{32}$$

If the increment of the total energy in all forms supplied to change the volume and temperature of the gas be $d\,h$, then

$$d\,h = k\,d\,\tau + d\,w \tag{33}$$

Now substitute the value of $d\,w$ from (32)

$$\therefore d\,h = k\,d\,\tau + \tfrac{2}{3}\,a\,k\,\tau\,d \text{ log. } v \tag{34}$$

Divide (34) by τ, etc.

$$\therefore \frac{dh}{\tau} = k\,d\,[\text{log. } \tau + \tfrac{2}{3}\,a \text{ log. } v], \tag{35}$$

from which it appears that the first member of (35) is a perfect differential; hence the second member is. But this is, as is well known, the fundamental equation of the second law of thermo-dynamics. It is to be remarked that it has been here assumed that a and k are constants, which they undoubtedly are very nearly, if not exactly, as will be shown later.

5. Experimental Verifications and Comparisons.

The equations (28), (31), etc., respecting the variations of temperature, volume and pressure of a permanent gas, are general, and, as a particular case, we shall first consider the experiments of Thompson and Joule* in causing air and other gases to expand freely in passing through a porous plug. In these experiments the variation of temperature is very slight, and the gases obey so nearly the law of Boyle, that we are at liberty to assume in (28), $d\,(p\,v) = p\,d\,v + v\,d\,p = 0$.

Hence (28) becomes

$$a\,k\,d\,\tau = \tfrac{1}{2}\,\Sigma\,(R\,d\,r + r\,d\,R) \tag{36}$$

In some of these experiments the gas, in passing the plug, expanded to more than four times its initial volume, so $d\,r$, the increment of the mean distance r of the molecules, must have been a considerable fraction of r. The terms in $R\,d\,r$ must be positive if the forces are attrac-

* *Phil. Trans. Lond. R. Soc.*, 1853, 1854, 1862; or *Wüllner's Experimentalphysik*, 3te Aufl. Bd. 3, S. 463.

tive, and express the work performed in moving the molecules through the distance $d\,r$ from each other against the attraction R. According to (36), if these were the only terms in the last member, or the larger ones, the temperature, *i. e.*, the kinetic energy, would be increased by passing through the plug, a result which would be in palpable contradiction to the principle of the conservation of energy; for $R\,d\,r$, the work done, must have been extracted from the internal energy of the gas, which would cause a decrease rather than an increase of temperature. The experiments gave a slight decrease of temperature, which shows that the terms in $r\,d\,R$ are, in this case, negative, and numerically larger than those in $R\,d\,r$.

Let us examine this point more at length. Since there was almost no variation of temperatue, R may, in this case, be taken to be a function of r expressed by the equation $R = f\,r^{-i}$, in which f is a numerical coefficient and i is a number for which various values (all greater than unity) have been proposed by different physicists in order to represent the actual attraction, more or less approximately, by the proposed equation.

$$\left.\begin{array}{ll} \text{If} & R = f\,r^{-i}, \\ \text{then} & R\,d\,r = f\,r^{-i}\,d\,r, \\ \text{and} & r\,d\,R = -\,i\,f\,r^{-i}\,d\,r, \\ \therefore & r\,d\,R = -\,i\,R\,d\,r, \end{array}\right\} \qquad (37)$$

from which it appears that the terms in $r\,d\,R$ are, on this supposition, of opposite sign from those in $R\,d\,r$ and i times as large; and (36) becomes

$$a\,k\,d\,\tau = \tfrac{1}{2} f\,(1 - i)\,\Sigma\,r^{-i}\,d\,r, \qquad (38)$$

in which the second member is negative if $(1 - i)$ is so, a result which is, as already stated, in agreement with experiment.

Far more decisive are the experiments of Andrews* upon the behavior of carbonic acid gas above the critical temperature. In these experiments the pressures were carried to more than 100 atmospheres, at different constant temperatures, in which case (28) becomes

$$-\,d\,(p\,v) = \tfrac{1}{3}\,\Sigma\,(R\,d\,r + r\,d\,R). \qquad (39)$$

By (37) this may be written

$$-d\,(p\,v) = \tfrac{1}{3} f\,(1 - i)\,\Sigma\,r^{-i}\,d\,r. \qquad (40)$$

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* *Phil. Trans. Lond. R. Soc.*, 1869, p. 575; or *Wüllner's Experimentalphysik*, Bd. 3, S. 680.

The following are the numerical results obtained at the temperature of 48·1°C., in which p is given in atmospheres, and the volume, v, of the gas, at one atmosphere, is taken as 1000:

p	v	$p v$
62·60	11·57	724·28
68·46	10·06	688·70
75·58	8·49	641·67
84·35	6·81	564·42
95·19	5·04	479·55
109·40	3·35	366·40

In treating this experiment as a compression, $d\,r$ is negative, and both members of (39) are then positive, while $r\,d\,R$ is shown by the numerical results to be much larger than $R\,d\,r$, and of opposite sign. Other results at temperatures nearer the critical temperature of 31°C. are perhaps more striking than that just quoted.

The experiments of Andrews, as well as those of Regnault and other physicists, have shown conclusively that, according as the temperature of an imperfect gas is augmented, it becomes more and more nearly perfect; *i. e.*, it approaches more nearly to the state in which there are no intermolecular forces. Hence, R is also a function of τ, and such an one that $d\,R$ is negative when $d\,\tau$ is positive; from which it appears that in (28) the terms in $r\,d\,R$ are in all cases of different sign from those in $R\,d\,r$. In fact, if the volume remains constant, the terms in $R\,d\,r$ vanish, because $d\,r = 0$ by (30).

Hence, combining this result with that previously arrived at, we see, if temperature and pressure be taken as the independent variables, that since $\Sigma\,d\,(r\,R)$ is negative for increments of each of these variables separately, it is so for both together, and hence is so always.

As another interesting example of the comparison of (28) with experimental results, let us consider Berthelot's* principle of the maximum work (*i. e.*, maximum heat) of chemical decomposition, which states that every chemical change accomplished without the intervention of energy from without, tends to the production of the body, or system of bodies, which sets free the most heat.

This is announced as a law of nature, the proof of which is to be found in a vast array of experimental evidence. It is evidently a law of fundamental importance to the theory of chemistry; and it seems

* *Essai de Mechanique Chimique*, 1879, t. 2, p. 421.

to depend theoretically upon the mechanical principles involved in (28), for at the instant of chemical decomposition the atoms must be regarded as separate bodies obeying the laws of stationary motion.

In order to introduce the condition of no exchange of energy with external bodies,

Let $$d\,v = 0, \quad \therefore p\,d\,v = 0;$$

i. e., there is no work done against external pressure, and if $v\,d\,p$ be small enough to be neglected, then (36) may be applied to this case. It appears, however, that the ordinary conditions of experiment from which the law was deduced would be better represented by supposing the pressure constant;

$$i.\ e.,\ d\,p = 0, \quad \therefore v\,d\,p = 0,$$

in which case $p\,d\,v$, the external work, is, as appears from experimental evidence, in general so inconsiderable as not to affect the correctness of the result, so that (36) may be considered, in this case also, to express approximately the mechanical relations involved. Considering now the case of $d\,v = 0$, the terms in (36) in $R\,d\,r$ are inconsiderable, since the mean distance cannot be greatly changed while the total volume remains constant. But the terms in $r\,d\,R$ depend principally upon the increase dR; *i. e.*, of the attraction between the atoms in the final chemical combination over that in the initial. If the atoms in the final arrangement obey the greater attractions, then $r\,d\,R$ is positive. But $r\,d\,R$ is numerically greater than $R\,d\,r$; hence by (36) heat is liberated, and the temperature is augmented. Hence, Berthelot's principle—that of several possible chemical decompositions in an isolated body, that one will occur which sets free the largest quantity of heat—follows as a direct consequence of the axiomatic truth, that the atoms will obey the more powerful attractions, which will necessarily determine the rearrangement of the atoms into molecules.

As further examples of the application of our formulæ, it may be noticed that (38) can be employed to discuss the stationary motion of other systems besides that of the molecules of a gas, such as orbital and central motions, in which we have $p = 0$, $\therefore d\,(p\,v) = 0$.

Let e be the mean progressive energy of the system, then (38) becomes

$$d\,e = \tfrac{1}{2} f (1 - i)\, \Sigma\, r^{-i}\, d\,r. \tag{41}$$

The only work done in changing the mean distances is

$$d\,w = \Sigma\, R\,d\,r = f\, \Sigma\, r^{-i}\, d\,r. \tag{42}$$

And the total energy supplied to the system is

$$d\,h = d\,e + d\,w = \tfrac{1}{2} f (3 - i)\,\Sigma\, r^{-i}\,d\,r, \tag{43}$$

from which it is seen that

$$d\,e = \tfrac{1}{2}(1 - i)\,d\,w, \qquad d\,h = \tfrac{1}{2}(3 - i)\,d\,w. \tag{44}$$

Take the case of the solar system in which $i = 2$, then by (44)

$$d\,e = -\tfrac{1}{2}\,d\,w, \qquad d\,h = \tfrac{1}{2}\,d\,w.$$

The first of these equations states that if the mean distances of the bodies of the system are slightly augmented, then the mean kinetic energy of the system in this new state of stable motion is less than it was befoɪe by one-half of the work expended in moving the bodies to their new positions against their mutual attractions. The second equation states that the total energy which must be supplied is only half the work expended, the other half being derived from the decrement of the kinetic energy just mentioned.

Next take the case of an elastic system in vibration, in which $i = -1$, then by (44)

$$d\,e = d\,w, \qquad d\,h = 2\,d\,w.$$

These equations state the well-known fact that in this case the kinetic and potential energies are equally increased.

It is to be noticed that when $i = 3$ no energy need be supplied to the system to augment the mean distances, and when i is greater than 3 energy must be supplied to decrease the mean distances,—a remarkable fact to be considered in connection with the value $i = 5$, which was proposed by Maxwell.*

6. Ratio of the Specific Heats of Permanent Gases.

Let $\varkappa\,k$ be the specific heat at constant pressure, and k that at constant volume expressed in mechanical units; then their ratio $\varkappa$ is the quantity in question, which has been determined experimentally for a number of gases with considerable accuracy. Its approximate theoretical value can be found as follows:

If (33) and (28) be applied to this special case, in which $d\,p = 0$, we have, by definition of $\varkappa\,k$, $d\,h = \varkappa\,k\,d\,\tau$.

Also,

$$d\,w = p\,d\,v + \Sigma\, R\,d\,r, \tag{45}$$

in which $p\,d\,v$ is the external work done, and the last term is the

* *Phil. Mag.*, S. 4, vol. 35, p. 133, 1868.

work done against intermolecular attractions. It will be noticed that there is no term in $d\,w$, as given, representing the work expended against interatomic forces. Were such a term needed, it would be also of the form $\Sigma\, R\, d\, r$, but its value is zero; for, suppose a molecule to consist of atoms held by elastic forces at certain mean distances, then these mean distances are not essentially changed by atomic vibration which alternately increase and decrease those distances, *i. e.*, $d\, r = o$ for each molecule. The periodicity of the lines in gaseous spectra observed by Stoney and Reynolds* shows pretty conclusively that the interatomic forces are of this character.

Hence, by (28),

$$d\, w = \tfrac{2}{3}\, a\, k\, d\, \tau + \tfrac{1}{3}\, \Sigma\, (2\, R\, d\, r - r\, d\, R). \tag{46}$$

Now let

$$\Sigma\, R\, d\, r = \beta\, k\, d\, \tau, \tag{47}$$

in which β is an extremely small positive numerical coefficient (which is zero for perfect gases), expressing what fraction the work performed against the intermolecular attractions is of the total increment of the kinetic energy. Then, by (37) we have the following approximate value of the last term of (46),

$$\tfrac{1}{3}\, \Sigma\, (2\, R\, d\, r - r\, d\, R) = \tfrac{1}{3}\, (2 + i)\, \beta\, k\, d\, \tau. \tag{48}$$

Substitute the values just given for the various terms of (33), and divide by $k\, d\, \tau$, and we obtain

$$\varkappa = 1 + \tfrac{2}{3}\, a + \tfrac{1}{3}\, (2 + i)\, \beta, \tag{49}$$

in which the value of a requires more extended consideration. Let b denote what fraction the increment of the mean rotary energy is of total increment $k\, d\, \tau$ of the kinetic energy, and let γ denote what fraction the vibratory energy, kinetic and potential, of the atoms within the molecule is of the same quantity.

Since these together constitute the total increment of the kinetic energy, we have

$$a + b + \gamma = 1. \tag{50}$$

But, in the general case, in which the molecules consist of more than two atoms, we have, by (13) and (23),

$$a\, k\, d\, \tau = b\, k\, d\, \tau + \tfrac{1}{2}\, \Sigma\, d\, (r\, R), \tag{51}$$

but by (37) and (47) this becomes (after dividing by $kd\tau$),

$$a = b + \tfrac{1}{2}\, (1 - i)\, \beta. \tag{52}$$

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* *Philos. Mag.*, S. 4, vol. 42, p. 41, 1871.

Add (50) and (52)

$$\therefore \quad 2a = 1 - \gamma + \tfrac{1}{2}(1 - i)\beta. \tag{53}$$

Substitute this value of a in (49)

$$\therefore \quad \varkappa = \tfrac{4}{3} - \tfrac{1}{3}\gamma + \tfrac{1}{6}(5 + i)\beta, \tag{54}$$

from which it appears, that when the vibratory energy is considerable, it will have an important influence in diminishing $\varkappa$, while the intermolecular attractions may exert some slight influence to increase $\varkappa$.

The experimental values of $\varkappa$, as given by Meyer,* lie between 1·33 and 1·25. If we disregard the terms in β, the corresponding values of γ are 0 and $\frac{1}{4}$. The larger values of γ belong, in general, to the more complex molecules, and we seem here to have an experimental measure of the amount of the mean vibratory energy, kinetic and potential. If β is large in these gases, then γ is thereby increased.

In the case, however, in which the molecules consist of but two atoms each, we have by (25) the following equation instead of (52):

$$\tfrac{2}{3}a = b + \tfrac{1}{3}(1 - i)\beta, \tag{55}$$

which combined with (50) and (49) gives

$$\varkappa = \tfrac{7}{5} - \tfrac{2}{5}\gamma + \tfrac{1}{5}(4 + i)\beta. \tag{56}$$

In this equation it is seen that β has a somewhat greater influence than it had in (54), while γ has probably a much less influence; there being but one pair of atoms to vibrate instead of three or more pairs, as in the previous case, the value of γ itself would, in general, be much smaller than before.

The most probable experimental values of $\varkappa$ for H_2, O_2, N_2, CO, NO, HCl, and air all lie between 1·41 and 1·39, that for air having been many times determined by the ablest experimental physicists. The mean value of $\varkappa$ for air, from many accordant determinations, is 1·405, while the value derived from Regnault's most accurate measurement of the velocity of sound is 1·3945, which numbers are taken from Wüllner,† who gives an extended account and comparison of these determinations.

In the case in which the molecules consist of a single atom each, we have

$$b = 0, \therefore a = 1 - \gamma \tag{57}$$

* Kinetische Theorie der Gase, 1876, S. 91.

† Experimentalphysik, 1875, Bd. 3, S. 461.

in which case (49) becomes

$$\varkappa = \tfrac{5}{3} - \tfrac{2}{3}\gamma + \tfrac{1}{3}(2 + i)\beta. \qquad (58)$$

The vapor of mercury is perhaps the only gas regarded by chemists as consisting of molecules of a single atom each, and for this gas, Kundt and Warburg* found $\varkappa = 1{\cdot}67$. The value of $\varkappa$ could also have been discussed by application of Clausius' equation (34) to the case of expansion at constant pressure, and results could thus have been obtained similar to those already found.

7. Concluding Remarks Concerning the Constitution of Gases.

The results which have been arrived at seem so to harmonize known facts respecting gases as to lend probability to the following statements:

(1.) Atoms have size and are smooth spheres—*i.e.*, are centres of force repulsive at very minute distances, and attractive at somewhat larger distances.

(2.) Molecules are systems of atoms held together by the atomic attractions and repulsions in which the mean distances of the atoms are not essentially changed by temperature or pressure, and probably not by liquefaction or solidification.

(3.) The mean rotary energy of the molecules is very nearly equal, in general, to their mean progressive energy; but is only two-thirds as much for diatomic molecules, and is zero for monatomic molecules.

(4.) The vibratory energy of the atoms within the molecules may be a considerable fraction (as much as one-fourth in the case of very complex molecules) of the total kinetic energy, and this vibratory energy should be regarded as wholly kinetic.

It has been thought improbable that the comparatively moderate progressive velocities of the molecules should originate the radiations of heat and light emitted by a gas, and hence that the atomic vibrations, which must be much more rapid, should be regarded as their mechanical cause. It has been then said that the energy of the vibratory motion set up within a molecule by an encounter must be rapidly expended in emitting radiations. Such, however, does not appear to be the fact, for in case radiations are caused by vibrations, then vibrations would apparently be caused as well by radiations from other bodies;

* Pogg. Ann., 1876, Bd., 157, S. 353.

so that a gas in equilibrium would thus receive the same amount of vibratory energy from without in the form of radiations as it loses. The vibration may, however, not be of uniform character during the interval between one molecular encounter and the next; it may take on a more regularly harmonic character as this interval elapses, and the energy of the irregular vibrations, or high harmonics, set up by the shock of the encounter may become transformed by the elastic forces into vibrations of less period, so that in a very rare gas, in which the encounters are comparatively infrequent, almost no vibrations, except those of an harmonic character, may be distinguishable.

At the same time, that part of the kinetic energy of the gas which is vibratory (the relative amount of which is evidently controlled by fortuitous molecular encounters) probably suffers no change by the frequency or lack of frequency of molecular encounters, in case any small amount of dissociation present may be disregarded. These considerations go to show that the fractions a, b and γ, which have been used, are of constant value, and that k must be so also.

Watson* in his treatise has investigated the ratio of the specific heats of a gas by the aid of generalized co-ordinates, expressing the number of degrees of freedom of the system of atoms in a molecule, and, though the investigation is one of great merit, it seems to me unsuited, in one particular, to the system treated; for it presupposes, as I understand it, rigid connections between the members of the system. Since an elastic connection is neither a degree of perfect freedom, nor of perfect constraint, but something intermediate, there is no integral number of degrees of freedom in the system. If molecules were rigid bodies, such systems would possess in general six degrees of freedom, and thus would have six generalized co-ordinates, which might be taken as three rectangular and three angular co-ordinates, such as have been employed in this paper. When, however, the molecules are smooth solids of revolution, the number of co-ordinates would be reduced to five, and, in case of smooth spheres, to three.

Now, if these are degrees of perfect freedom, it seems demonstrable that the kinetic energy which is distributed among them by fortuitous encounters would be equally shared by them—*i.e.*, the energy with respect to each co-ordinate would be of the same amount, a result which agrees with what has already been proved for perfect gases. But in case partial constraints, not amounting to the loss of entire

* Kinetic Theory of Gases, 1876, p. 38.

degrees of freedom, are introduced with respect to any of the co-ordinates, the energy will no longer be equally distributed among all the co-ordinates, but will be influenced by these constraints. This is what was found to take place in imperfect gases, where the intermolecular attractions affect the components of the progressive motion, but not the rotary components.

In many points the results arrived at in this paper are in substantial accordance with those found by Boltzmann* in his important papers upon this subject; but both he and Watson regard some of the experimental values of κ, and in particular all values less than 1·33, to be in contradiction to theory. So far as is known to the author, the investigation which he has here given to the question explains for the first time this contradiction which Watson (p. 39) regards as "the great difficulty in the establishment of the kinetic theory of gases on the molecular hypothesis."

CINCINNATI, January 18, 1883.

ANTICYCLONIC STORMS.

By PLINY EARLE CHASE, LL.D.

The science of Meteorology may, for many good reasons, be regarded as a peculiarly American science. William Ferrel's discussion of the motion of fluids and solids relative to the earth's surface, which was first published in the summer of 1856, placed the laws of cyclonism and anticyclonism on a solid mathematical basis. He showed that, in the northern hemisphere, all moving bodies are constantly subjected, in consequence of the earth's rotation, to a deflection towards the right hand. Hence all atmospheric surface currents which are mainly governed by a downward pressure, tend to curve in the direction of the hands of a watch, or successively through north, east, south, west. All surface currents which are mainly governed by an upward pressure, tend to flow in an opposite direction, or through north, west, south, east.† The heavy winds are called anticyclonic; the light winds, cyclonic.

* Sitzungsb. d. Wien. Akad., Bd. 63, 66, 74.

† This will be evident, if we imagine ourselves to be lying in the current and facing the direction towards which the pressure tends.

There can be no descending currents in one place without ascending currents in another; therefore, in every atmospheric disturbance, there must be simultaneous cyclonic and anticyclonic winds. Such disturbances originate either in an unusual cooling and condensation, or in an unusual heating and expansion of air. In the former case the inflow, in the upper regions of the atmosphere, will produce an increased pressure. In the latter, the outflow will produce a diminution of pressure. In the restoration of equilibrium, currents of warm air are often brought into contact with colder currents. If the currents are both saturated wtth moisture, or if they contain more vapor than can be retained under the temperature of the mixed currents, precipitation takes place, in the form of rain, hail, or snow This precipitation reduces the weight of the atmospheric column and the barometer falls. Accordingly, there is a constantly increasing tendency to cyclonism about storm centres, and there has been a very prevalent disposition to look upon all storms as of cyclonic origin.

A little reflection, however, will show that the initial mixture of currents may be due to either of the causes above mentioned; either to the flow of warmer air into a cold depression at the top of the atmosphere, or to a flow of cold air, at the earth's surface, towards a region of low barometric pressure. In the former case, the initial superficial currents are determined by a downward pressure and they are, therefore, anticyclonic; in the latter they are determined by an upward pressure and are cyclonic.

A careful study of the weather maps shows that the heaviest rains and snows occur in advance of the centres of low barometric pressure, or in the rear of the centres of high barometric pressure. If storms began in the cyclonic currents, the reverse should be true; the greatest effect following the low centre and preceding the high centre.

The frequent failures of forecasts, during the past winter, seem to have been mainly due to a misinterpretation or a misconception of these facts, to which the writer first called attention in 1871 (*Proc. Amer. Phil. Soc.* XII, 40). They were subsequently embodied in the "Suggestions" of the Signal Service Bureau, and the officers of the Bureau communicated to the public journals, some remarkable evidences of anticyclonism in storms of great magnitude.

Loomis's subsequent discussions of the Signal Service observations have furnished abundant additional evidence of a like character, and

have shown the great frequency of anticyclonism at the beginning, and during the continuance of showers and of storms of all kinds.

The limit between anticyclonic and cyclonic tendencies, may be approximately assumed to be midway between the centres of high and low barometric pressure. All cloudiness or precipitation between the limit and the high centre, represents anticyclonic influence; all between the limit and the low centre represents cyclonic influence. Local cyclonism sets in soon after precipitation begins, and the anticyclonic influence is thus partially hidden; but a critical examination of the weather maps will show that the prevailing currents of the region often continue to be anticyclonic until the rain or snow is nearly, or quite over. The evidences of storm breeding and stormy anticyclonism will be still more striking, if the changes of barometric pressure are studied in connection with the beginnings and subsequent growth of cirrus, cumulus, and nimbus clouds, as well as with the rainfall and the final breaking up of cloudiness.

There are good reasons for believing that such study, systematically and thoroughly continued under the direction, and with the facilities of the Signal Service Bureau, would raise the successful verifications of the Washington forecasts to an average of at least ninety-five per cent.

THE GEOLOGY OF PHILADELPHIA.

By Professor H. Carvill Lewis.

[A lecture delivered before the Franklin Institute, January 12, 1882.]

Some years ago, Dr. C. C. Abbott, of Trenton, announced his discovery in this gravel of stone implements of human workmanship, distinct in shape and characters from those of the modern Red Indian. They are larger and more rude than modern implements, being roughly chipped and never ground to an edge or polished. Unlike modern arrowheads and spearheads, which are generally made from quartz, flint or some hard sandstone, these are all made of gray argillite, a rock which is found in places farther up the river, and which is a Triassic shale altered and hardened by the heat from adjacent trap dykes.

They are essentially of *palaeolithic* type, and have identical characters with the river drift implements found in the valleys of France, England, and other parts of Europe. Dr. Abbott states that the modern implements ("neoliths") are confined to the surface of the ground or a few inches below, but are never associated with the "palaeoliths" lower down, which may occur at depths of ten feet or more below the surface. When found below the surface, these palaeolithic implements always occur in the Trenton gravel, and never in the older gravels, and this fact alone offers strong evidence that they belong to and are of coeval deposition with that formation. In going over the ground in company with Dr. Abbott, it was interesting to find that it was only within the limits of the Trenton gravel, as previously traced out and mapped by the lecturer, that these implements had been found below the surface. Many competent archæologists sustain Dr. Abbott in believing that these rude implements are a constituent part of the gravel, and are neither natural forms nor intrusive objects.

All the evidence that has been gathered points to the conclusion that at the time of the Trenton gravel flood, man in a rude state lived upon the banks of the ancient Delaware. He may have been in the habit of spearing fish and seals with spears pointed by his rough stone implements, and these having been dropped into the flood may have sunk into the loose and shifting gravel. The climate was cold and the flooded river was filled with icebergs. A similar period in Europe has been called the *Reindeer Period.*

It is interesting to find, as pointed out by archæologists, that until lately the Esquimaux have used rude stone implements similar in appearance to those found in the Trenton and other river gravels, and it has been suggested that that race, now living in a climate and under conditions perhaps similar to those once existing on the Delaware, may have some kinship with the pre-Indian people of this river. It may be that an Esquimaux race, living here at the time of the flooded Delaware, were driven north by the coming of the Red Indians.

Whether or not these ancient people were the ancestors of our present Indians, it is of interest to find their great antiquity, as shown by the Trenton gravel. As already stated, that gravel was deposited at the close of the last glacial epoch. The conditions at that time have already been described, and in the last lecture an attempt was made to calculate the probable date of that period. A careful search among

the more recent gravels underlying Philadelphia, might throw more light upon this yet unsettled problem.*

Coming now to the second portion of our subject, being a description of the *rocks* in the vicinity of the city, time forbids more than a cursory examination.

THE PHILADELPHIA GNEISS.

The above described superficial formations rest upon an ancient metamorphic rock, composed of quartz, felspar, and mica, arranged in layers, and known as *gneiss*, and thus frequently in the same street cutting a section may be exposed of one of the most recent deposits lying directly upon one of the most ancient geological formations known. The age of the glacier is as nothing in comparison with that of the gneiss. The latter forms the old foundation stones of the continent, from which all the other rocks were afterwards formed. The flakes of mica in the sandstones of the coal strata and in the brownstone used for our houses, are derived from this ancient formation of gneiss, which has been the bed of many an ocean. Underlying all the other rocks of the globe, the *Archaean* rocks were made at the time when the lowest forms of life were introduced. Of the archaean rocks, the oldest are the *Laurentian*, to which the gneiss near Conshohocken probably belongs, and the newer are known as *Huronian*. To this division belongs the gneiss at Philadelphia, which is identical with the gneiss which forms the White Mountains of Vermont and the Rocky Mountains of Colorado. From the former locality it is sometimes called *Mont-Alban*. These ancient rocks are always greatly twisted and contorted, generally dipping at high angles to the horizon, as may be seen along the Schuylkill in the East Park.

As the earth contracted during its cooling from the molten state, its crust shrivelled and became wrinkled like the skin of a dried apple. The strata were tilted up to form mountain chains, which were afterwards ground down by long continued erosion. No life could exist until the earth had cooled down to 200° F. Some idea of the length of time before that stage is given in Helmholz's calculation, based upon the rate of cooling of lavas, that for the earth to cool from 2,000° to

*At the opening of the lecture, Mr. John Sartain brought for examination a supposed Indian implement found by him in gravel, 24 feet below the surface of the street, in an excavation below the cellar of No. 728 Sansom street, Philadelphia. This implement has since been described in full by Prof. Lewis, in the Proceedings of the Academy of Natural Sciences, Feb. 6, 1883.

200° F., would have required three hundred and fifty millions of years. Any life that may have existed in the Philadelphia gneiss has been obliterated by the heat, pressure, contortions, and consequent metamorphism to which it has been subjected. These same forces, however, have made our rocks so full of interesting minerals. Minerals and fossils, therefore, rarely occur together.*

The beds of serpentine which occur in the gneiss of the northern part of the city, are regarded as the result of the alteration of gneissic rocks by contact with magnesian waters.

THE PRIMAL SLATES AND POTSDAM SANDSTONE.

On top of the gneiss and at the base of that great group of fossiliferous rocks known as the Palaeozoic system, is a peculiar formation in the middle strata of which occur the oldest fossils yet found in the vicinity of Philadelphia. The lower part of the formation is the pale sandy slate which forms Edge Hill and Barren Hill, and the northern base of Chestnut Hill. The slates are closely folded and stand often almost perpendicular. At Edge Hill station on the N. P. R. R., the strata are broken and bent over by the action of gravity draging them down hill—this phenomenon being known as "creep." These slates (known as hydro-mica slates) are probably of the same age as the diamond bearing slates of Brazil and elsewhere.

A sandstone, which from its great development at Potsdam, N. Y., has been named from that place, overlies the slates and often contains long tubular fossils, known as *Scolithus linearis*, which appear to be the casts of worm-holes. As shown by the ripplemarks, this sandstone was formed at the edge of an ancient sea. Marine worms burrowed in the sea beach and the winds drifted the sands, which ages afterwards were hardened and tilted up to form the rocks at Willow Grove, and those along the north side of Chester valley.

On top of this fosiliferous sandstone is a series of soft, iron-bearing shales, often decomposed into variegated clays, carrying extensive beds of iron ore (limonite). Crossing the limestone valley, diagonally, in a series of anticlinal rolls, which rise through the overlying limestone, this formation supplies a large amount of iron ores to our blast furnaces.

* The principal minerals in the Philadelphia gneiss were given, and the boundaries of the formation were shown upon a map. It was stated that no accurate geological map of this region had yet been constructed.

THE AURORAL LIMESTONE.

The bluish-white streaked marble which adorns the door steps and window sills of the greater part of our houses comes from the limestone valley which, on either side of the Schuylkill, lies immediately north of the city. Originally formed by the accumulation of minute organic remains under deep sea water, subsequent changes have obliterated all traces of animal life, the streaks of carbonaceous material and the occasional specks of graphite alone remaining as witnesses. These same changes have altered certain strata of the limestone to the crystalline state known as marble. The quarries at Marble Hall are well worthy of a visit. Farther inland, in places removed from the disturbing influences of the Philadelphia region, the same limestone is filled with fossil shells and corals. Professor Rogers called it the "Auroral" limestone because it was the dawning of the long geologic day of the succession of Palaeozoic life.

Like almost all limestones, the Auroral limestone always occurs in a valley. These valleys, such as that north of Chesthut Hill, are such from the fact that the limestone for countless ages has been constantly dissolved away by the power of rain-water, and the surface lowered by the breaking down of underground caverns. On the other hand, the Kittatinny mountain is a mountain, not because its rocks are more tilted up than other rocks, but simply because the hard sandstone which forms it has resisted these atmospheric and erosive agencies, while the country on either side of it has been lowered.

The *iron ore*, so common in the valley north of Chestnut Hill, most of which is in the form of *limonite*, has been derived by solution and subsequent segregation from the older underlying shales, some of it having been altered in place from these shales, some of it belonging to clays of tertiary age, and some of it having been drifted still more recently and made a surface deposit. The lecturer several years ago discovered *lignite*, or brown coal, at some localities in the vicinity of Marble Hall. It had the form of twigs and branches, and, associated with kaolin, potter's clay and iron ore, threw light upon the age of these deposits.

THE TRIASSIC SANDSTONE.

A succession of red sandstone and shales, which, from its threefold division in Germany has been called the Trias, and which belongs to Mezozoic time, being more recent than the coal measures and older than the New Jersey marl, forms in Pennsylvania a belt, the lower edge of which extends from Trenton to Norristown and Valley Forge,

whence it traverses Berks, Lancaster, York and Adams counties, entering Maryland south of Gettysburg. The strata all dip at a low angle northwestward, and appear to have been deposited in a shallow estuary or inland sea which once occupied this region. As shown by the composition of its pebbles, this Triassic sea washed the shores of the Philadelphia mountains.

This was the age of reptiles. Labyrinthodonts waded in the mud-flats and left their tracks preserved to this day. Some of them walked altogether on their hind legs like a kangaroo, looking probably like a long-legged frog covered with scales, with teeth several inches long, and tall enough sometimes to look over a twelve-foot wall. Other creatures, called Dinosaurs, were like four-legged birds, the hind feet being bird-like. One of these, which had teeth like a crocodile, lived at Phœnixville, where its bones have been found. The footprints of these creatures, the mud cracks and ripple marks and rain prints, the cycads and tree ferns, and the occasional seaweeds, all tell the story of this formation and give fresh interest to that part of it which, under the name of "brownstone," is used for the fronts of our Walnut street houses.

As the Triassic age drew to a close, there was an outburst of volcanic action. Streams of molten lava issued from the earth to form the trap dykes which are crossed by the Reading Railroad at Conshohocken, by the North Pennsylvania Railroad near Quakertown, and by the Pennsylvania Railroad twenty miles before reaching Harrisburg.

The sketch here given of the geology of Philadelphia is but a fragment of what may be learned at our very doors. The gneiss of which our cellars are built takes us back in thought to that remote time when the earth had just cooled sufficiently to permit the introduction of the lowest forms of life; the marble of our door-steps tells of an ocean inhabited by no fishes, which washed land upon which grew no trees; our brownstone fronts recall an age of strange reptiles and uncouth birds, when seaweeds grew on the hills back of Norristown, and when earthquakes cleft open the earth; the bricks of our walls teach us of an epoch when the city was under water, the Schuylkill joined the Delaware at the Falls, and icebergs floated down from the great glacier farther north; and the cobble-stones, finally, mutely speak of that age of cold, preceding our own, when the glaciers melted and retreated, and when, on the banks of the flooded Delaware primeval MAN first appeared.

REPORT OF THE SPECIAL COMMITTEE OF THE FRANKLIN INSTITUTE ON THE PREVENTION OF FIRES IN THEATRES.

[Presented and accepted at the stated meeting of the Institute held Wednesday, April 18, 1883.]

HALL OF THE INSTITUTE, April 18th, 1883.

The majority of the "Committee on Prevention of Fires in Theatres" makes the following report:

Theatres for two hundred years have not materially changed in form or arrangement, yet they have enormously increased in size.

The building materials employed for the stage have, however, remained the same (except that in many cases the joists of the stage floor are I beams of iron); they are at present, as they formerly were, filled with masses of wood-work, boards, laths, canvas, gauze, etc., piled up as if it was the sole purpose of the builders to crowd together as many inflammable substances as possible.

The only important changes in theatres have been, first, the introduction of gas lighting; and second, appliances for heating, both of which have tended to greatly increase the hazard.

Without going into any detailed statistics, your committee shall give a few tables, compiled from the records of Foelsch and Hexamer, which are particularly instructive and interesting. For example, of 616 theatre fires there have occurred:

In London	35
In Paris	29
In New York	27
In San Francisco	21
In Philadelphia	17
In Boston	11
In Cincinnati	9
In New Orleans	8
In Baltimore	6

It is an alarming fact that the number of theatre fires is continually increasing. Sixty-nine occurred between 1851 and 1860, ninety-nine occurred between 1861 and 1870, 181 occurred between 1871 and 1880.

During the last decade we have had theatre fires as follows:

1871	20
1872	13
1873	15
1874	15
1875	14
1876	19
1877	17
1878	20
1879	25
1880	23
1881	28
Total	209

Average, 19.

Nineteen theatres have therefore on the average been destroyed during the last eleven years.

In a recent compilation your committee found that in 1882 twenty-three theatres were destroyed by fire.

Out of a great number of theatres, of which the age had been carefully ascertained, it is found that five out of two hundred and fifty-two theatres were burned before they were entirely finished or opened to the public; seventy were burned during the first five years after they had been built; thirty-eight were burned from the sixth to the tenth year of their existence; forty-five from the eleventh to the twentieth; twenty-seven from the twenty-first to the thirtieth; twelve from the thirty-first to the fortieth; twenty from the forty-first to the fiftieth; seventeen from the fifty-first to the sixtieth; seven from sixty-first to eightieth; eight from the eighty-first to the one hundredth, and three after the hundredth year of existence. From this table, which gives the longevity (if this expression may be allowed) of two hundred and fifty-two theatres, of which there are authentic accounts, may be seen that in the first five years nearly one-fourth were destroyed, while only three reached the age of one hundred years.

There is, perhaps, no fact which illustrates to us the frequency with which these fires occur so clearly as the repetition of these catastrophes at the same theatre. The following is a list of theatres which were three times totally destroyed by fire: Her Majesty's, London; Drury Lane, London; Covent Garden, London; the Emperial Opera House, Moscow; Barnum's Theatre and Museum, New York; the Royal Theatre, Glasgow; the City Theatre, Namur; the Teatro Sao Pedro, Rio-

The following is a list of theatres destroyed four times; Astley's Amphitheatre, London; the Grand Opera, Paris; the City Theatre, Brunn; the National Theatre, Washington; the Bowery Theatre, of New York, leading the list, it having been five times totally destroyed by fire in less than forty years.

There is no more vicious argument than that which is frequently made, that it is unnecessary to improve theatres in our country, as they are much superior to those of Europe; lengthy arguments of this sort generally ending with the statement, that fewer theatres are destroyed by fire in the United States than any other country. To dispel such ideas from the public mind, your committee quotes the statistical comparison from the records of Foelsch and Hexamer, with the following astonishing result.

In grouping the six hundred and sixteen theatre fires, which have been recorded according to the countries in which they occurred, we have the following:

In the United States	188
In Great Britain	87
In France	73
In Germany	53
In Italy	50
In Austria	33
In Russia	28
In Spain	21

All other smaller European States, fifty-six; all the other smaller non-European States, twenty-seven.

Your committee did not wish to make a report until it had thoroughly considered *how* the great number of fires at theatres, which is yearly increasing could be lessened, by the introduction of proper precautions; and by what means places where thousands congregate, not by necessity, but for pleasure, could be made entirely safe.

The consideration of the subject was taken up in the following order: The hazards of, (1) artificial light; (2) heating apparatus; (3) fire-works; (4) the use of paper wads in guns, and (5) the situation of the necessary workshops, paint lofts, spontaneous combustion of waste, etc.

After proper consideration of these subjects, your committee next studied methods for the improvement of theatres in regard to public safety, studying closely (1) the improvement of exits; (2) the division of the stage and rooms belonging thereto from the auditorium;

(3) the opening of doors; (4) safety systems of lighting, heating, ventilation, etc.

The greatest number of fires are caused by the paraphernalia of illumination. The danger of coal-oil, which is much used in our country and western theatres as an illuminating agent, is self-evident, but the hazards of gas, which but within a few years was the safest material at our command, are not so well understood. Besides the dangers of leakage and explosions, we have, in the case of gas illumination, hundreds of *flames* spread throughout a building, each forming a dangerous sphere around itself. Although the last named dangers can and should be lessened by proper precautions, such as wire baskets and shields over the flames, still, when we consider the close proximity of the border lights to combustible gauzes and canvas, and ponder on the hazards of temporary illuminating effects, where jets are fed through rubber hose which must be removed during change of scene, we must ask is there no other method of illuminating by which equally good artistic effects may be produced, and which at the same time will lessen or entirely do away with the hazards of the present system? Fortunately means are now at hand. By the labors of eminent electricians, we have at our disposal an agent by which the same, if not more brilliant, effects than those of gas can be produced, while doing away with the dangers of gas, the lamps themselves being absolutely safe. The finest piece of gauze might lie on one of these lamps without being harmed. At the same time the oppressive heat and deleterious products of the combustion of gas are done away with.

Your committee does not deem it necessary to describe the systems of "Incandescent Electric Lighting," the introduction of which would undoubtedly be one of the most necessary reforms of our present theatre system.

Your committee does not think that the arc light could be introduced to advantage in theatres, except in conjunction with reflectors so as to increase the brilliancy of the incandescent lamps. The disadvantages of all arc systems would be (1) their unsteadiness; (2) the color of the rays which would, as actors say, "bring out the paint," and by the want of warmth be disagreeable to audiences. The immense advantages of electric incandescent lighting, assisted by reflected arc lights over that of gas is, that it would do away with (1) the dangers from leakage and explosions of gas; (2) the oppressive heat of the numerous gas flames, which dries out the woodwork, canvass, and ropes of

the rigging loft, like tinder; (3) the fading of metallic colors caused by the products of gas combustion; (4) the very expensive processes of ventilation, which frequently do not give a sufficient supply of fresh air, may be greatly simplified as it is the great number of gas flames consuming more oxygen than the audiences do, which produces the "closeness" of theatres, and (5 and lastly) the fire hazard from contact with the light, as the glowing parts with the incandescent lights are hermetically sealed inside of a glass globe. Your committee is fully aware of the fire hazards of the electric light, but the incandescent lights (and especially our American systems) are, through the efforts of different committees, and foremost by that of the "New York Board of Fire-underwriters," so well supplied with safety "cut-outs" and "catches," and the erection of electric systems in the principal American cities is so well looked after by the special inspectors of the "Boards," that these dangers are reduced to a minimum. The practicability of electric light for the illumination of theatres, has been illustrated in the Savoy Theatre of London, which has for over a year been illuminated with electric light, proving it to be "a perfect artistic success."

Your committee has received the following letter from the management of the Savoy Theatre:

"In reply to your inquiries (1) The electric light is a perfect artistic success. (2) It costs, at present, about twice as much as gas in England, but the proposition here would, no doubt, be much less, as gas is much dearer than in England. Ultimately, no doubt, the cost in England will be the same.

Yours, faithfully,

R. DOYLY CARTE."

Theatres should be heated by steam or hot water systems. Stoves and heaters are objectionable. Where heaters are used, one-fifth of the registers should be so arranged that they cannot be closed, as many fires have been caused by overheated hot air pipes, in cases where all registers have been closed and the hot air could not escape. All register openings should be closed by fine wire netting to prevent combustible particles dropping into hot-air flues.

The only manner in which the dangers of fireworks may be lessened is by "*impregnating*" all scenery and gauze by approved processes. Your committee has for the past six months experimented with all ascertainable processes of impregnation. A process which your committee has found to be deserving of entire public confidence is that of Dr. J. Pafen, of Frankfort, Germany, which has been introduced to great extent; of its many commendable properties the following have

been certified on inquiry. The material may be used on scenery which has been painted upon, without destroying or injuring the colors; scenery which is impregnated in this manner does not, on being used, fill the air with a fine dust, deleterious to actors and singers, which was found to be a most disagreeable feature in other processes.

Your committee, at its request through the kindness of Messrs. Mertz and Schaede, received the following testimonial:

Frankfort-on-the-Main, August 2, 1882.

We herewith certify, on request of Messrs. Gustav Schaede and C. Rudolph Mertz, who have purchased the sole right to impregnate combustible substances for North and South America from Dr. Pafen, of this city, that after one year's use the following results have been obtained:

1st. The objects impregnated have proved, even after considerable length of use, to be perfectly incombustible.

2d. This quality has not been diminished by use in the least, as we have ascertained by repeated tests.

3d. The fabrics and colors have not suffered by the impregnation.

4th. No injurious effect of any kind have been observed to occur by Dr. Pafen's method on the voices of the singers and actors.

C. Rudolph,
Engineer of the Opera House.
Magnus Proesler,
Inspector of the Opera House.

Satisfactory results have also been obtained by the processes of Gautsch, Judlin, by sulphate of ammonia, and by silica deposited into the fibres by precipitation.

Besides impregnating the scenery, the woodwork should be covered with some fire-proof paint. Your committee experimented with all the solutions they could ascertain, and had most satisfactory results from "asbestos paint," and especially from the so-called asbestos concrete.

Paper wads in guns and pistols, by settling on gauze or canvas while still glowing, have repeatedly caused theatre fires. Your committee believes that the practice of using wads of hair, would overcome this hazard. Quick burning powder is recommended for theatre firearms; since the sole purpose is to make a noise, and slow burning powders, especially *soda powders,* being deliquescent; such grains of powder will, when ignited, be carried in a burning condition considerable distances from the muzzle of the gun, thus readily igniting combustible objects.

The workshops and paint loft should be located outside of the

theatre proper, and should communicate with the stage only by double iron lined doors with stone sills.

Your committee has thought best to bring all minor matters into a series of recommendations, but before proceeding to give them must mention that there are important automatic devices for opening a smoke flue above the stage, lowering the fireproof curtain, and sending an alarm, none of which have, however, been introduced into the United States.

Your committee have sought much to find a good fire proof drop curtain.

The results obtained of woven asbestos *cloth* were most satisfactory, and smaller experiments, as well as one performed on a large scale at the Brooklyn Navy Yard, convinced your committee that it makes an excellent fire curtain.

Transparent wire drop curtains are objectionable, as in case of fire they allow smoke to pass through them, and by not cutting off the view of the fire from the auditorium, increase the panic.

Your committee does not think that the curtain used at the new Opera House at Geneva is much better.

This consists of a wire screen of very fine meshes, like the material employed for a Davy's safety lamp, they being covered on both sides with a coarser wire netting. Curtains of this kind have not yet stood the "fire test." Your committee believes that in case of fire it will not be of better service than the ordinary wire curtain.

The curtain recently constructed for the new theatre "des Celestins," at Lyons, is constructed on a similar principle to the above, and is hemmed in by a border of sheet iron two metres broad. Although this will somewhat reduce some objections, yet it is not a commendable curtain.

At Lyons, Lille, Toulon, and for the new "Theatre des Arts," at Rouen, curtains of iron have been introduced. These consist of a number of horizontal slats put together like venetian window blinds, and are raised and lowered by hydraulic apparatus. Whether such curtains will in the course of time prove themselves successful, is still problematical. The two great objections which your committee sees in these curtains is their tendency to rust, and the ease with which they would warp at large differences of temperature, as in case of fire.

Sliding curtains of corrugated sheet iron have stood best in case of

fire. They have been employed with great success at the Hof Theatre, Dresden; Central Halle, Hamburg; Hof and National Theatre, Munich; New Opera House, Frankfort-on-the-Main; Wallmer and Friedrich-wilhelmstadter, Belle-Alliance Walhalla, and Central Theatres at Berlin; Concordia Theatre, Hamburg, and others.

Your committee cannot too strongly bring out the fact that the regulating apparatus of the curtain should be on the stage; and not, as was the case at Vienna, in the rigging loft, a place which in case of fire immediately becomes inaccessible. If the apparatus is one which is set in motion by a crank, the handle should be so fixed that it cannot be removed, or it will in most cases be taken off in order to gain room, be stowed away somewhere, and will at the moment of danger be missing.

Your committee heartily endorses the action of the authorities of Vienna, who now require a man posted at the safety curtain lowering apparatus during all performances.

Your committee has had no chance of testing the patent curtain of Carl Pfaff, but from the report of the special committee of the "Oesterreichischen Ingenieur und Architekten-Verein," has been convinced that it is one, if not the most meritorious fire curtain known up to this time; the above committee after careful tests gave the following report of its properties: (1) That a curtain constructed on this principle could be used daily with surety and with a small amount of trouble. (2) That they were satisfied of the durability of the proposed invention. (3) That in case of fire the invention would work with rapidity. (4) That it would give the auditorium the necessary protection. (5) That it would restrict the fire to the stage.

Your committee begs leave to submit the following recommendations, many of which are already law in several European States:

First. All corridors should increase in width from the theatre to the open air.

Second. All extra exits (fire corridors) should be marked as such in large, bold letters; should be lighted by oil lamps (not petroleum products; sperm or lard oil is recommended), and should be unbarred from the opening of the theatre until it is closed. Before the close of every performance they should be opened, that the extra exits may become known to the public.

Third. All doors should open outwards.

Fourth. Bannisters or railings should be fastened to the walls of all

stairways; they should be fitted into grooves in the wall; enough room being left between the rail and the groove to allow hands to slide freely on the rail.

Fifth. Long rows of seats should NOT be permitted. Rows should be cut by an aisle at least at every twenty feet.

Sixth. Movable seats should not be allowed. Seats should be tightly screwed to the floor. Fixed chairs with a spring attachment, which throws back the seats when not occupied, are strongly recommended.

Seventh. No scenery, properties, materials, or impediments of any description should be allowed to remain in corridors.

Eighth. The stage should be divided from the auditorium by a fire-proof drop curtain. Transparent wire curtains should not be used for this purpose.

Ninth. The fire-proof drop curtain should be kept down at all times except during rehearsals and performances; after which it should be immediately let down, and not raised until fifteen minutes before the beginning of the next performance.

Tenth. Doors and openings in the proscenium wall should be with stone sills, iron lined (on both sides), and should be self-closing.

Eleventh. The system of lighting the stage should be separated from that of lighting the auditorium; each should have a distinct feed-pipe or circuit.

Twelfth. Gas flames should (without exception) be covered by wire baskets. These baskets are to be made sufficiently large, so that the wire may never be heated to a greater temperature than 250°.

Thirteenth. Border and foot lights should be lighted by electricity, *not with an open light.*

Fourteenth. Every theatre should be supplied with a sufficient number of fire hydrants, with hose and nozzle attached ready for instant use, and not removable.

Fifteenth. A large reservoir, holding at least eight thousand gallons, should be placed over the auditorium ceiling; kept at all times full of water, connecting with the stand-pipes, and not allowed to freeze.

Sixteenth. A sufficient number of fire buckets (used in case of fire only) kept always filled should be distributed conspicuously over the premises.

Seventeenth. Every theatre should have a number (varying with the size of the theatre) of fireman.

Eighteenth. In order to keep control of the various theatres, a theatre inspector should be appointed in each town, who should have full power to enter every theatre at any moment, and whose duty it should be to see that these or other suggestions made law by an act of legislature, are faithfully carried out.

Nineteenth. The testing of all gas pipes, hydrants, and fire appliances should be performed at least four times a year, and oftener if the theatre inspector requires.

Twentieth. Every theatre should be connected with the nearest fire station by numerous electric alarms, most of which should be automatic.

Twenty-first. The theatre should be patroled at day and night, by watchmen, who should be controlled by watch-clocks, distributed over various parts of the building.

Twenty-second. No smoking should be allowed in the theatre, except where required on the stage in the representation of plays.

Twenty-third. No swinging gas brackets should be allowed in any part of the theatre.

Twenty-fourth. Woodwork which is within eighteen inches of a gas flame should be covered with sheet iron or tin, but in such a manner that air may circulate between the iron and the wood.

Twenty-fifth. Border lights should be so enclosed that no part of the enclosing body may be heated to a higher temperature than 250° Fahrenheit.

Twenty-sixth. Where heaters are employed the registers should be covered by fine wire netting, and at least one-fifth of the registers should be so arranged that they cannot be closed.

Twenty-seventh. Scenery and other stage supplies should not be stored on the stage, but in a separate *fire-proof* dock.

Twenty-eighth. No more scenery should be put upon the stage than is necessary for, at most, two performances.

Twenty-ninth. The use of fireworks, Roman candles, red fires, etc., should only be permitted when it has been shown to the "*Theatre Inspectors*" satisfaction that the scenery and gauzes have been impregnated by proper substances, and that the woodwork has been covered by some satisfactory solution.

Thirtieth. Wads of pistols and guns should be of hair only (not paper or cotton).

Thirty-first. If straw, hay or any other easily inflammable substance

be required in a scene, it should be removed to a fire-proof place immediately after the scene in which it is used.

Thirty-second. A large smoke flue should be provided above the stage. Automatic devices are recommended.

Thirty-third. That the public itself may have control in this matter, a complaint book should in every theatre be laid open to the public, where any individual may enter any faults of construction or arrangement which he has noticed. This book should not be the property of the proprietor of the theatre, but should belong to the "Theatre Inspector," the Fire Marshal, and Building Inspector of the city.

Thirty-fourth. Numerous permanent iron ladders should be fixed on the outside of the building, so that the firemen may readily enter the theatre while the corridors are still filled by the departing audience.

Thirty-fifth. Oil lamps should be cleaned and trimmed in a separate lamp and oil room, where, also, the oil should be stored. Oily rags and waste should be kept in small quantities only, and in iron boxes closed by an iron lid, and standing on brick, or other fire-proof substance, and as soon as they accumulate should be burnt.

Thirty-sixth. The workshops and paint loft should be outside of the stage building.

Thirty-seventh. Automatic sprinklers and steam jets should be placed over and on the stage. (The theatres of Boston are required by law to protect the stage by a system of automatic sprinklers. In November, 1882, a fire was extinguished at the Providence Theatre Comique, during a play, by automatic sprinklers, with so little injury, even to the scenery, that the performance was not stopped).

Thirty-eighth. Ground plans of the auditorium, giving a clear idea of the building, corridors, stairways, etc., should be prominently located in the halls, and should be printed on the back of programmes.

Your committee is well aware of, and have followed with sympathy and hearty approval the labors of the Asphaleia, a society of prominent German and Austrian technologists, who have made it their purpose to construct a theatre up to the requirements of our time, which should not only fulfil all technical qualities, but bring the theatre to an artistic perfection which it now lacks. This work your committee thinks they have almost accomplished, and all new theatres should be built according to their suggestions.

Your committee has tried to correct objectionable and suggest better features in theatres as they now exist, and has especially tried to make suggestions in reference to American theatres.

Your committee at first intended to inspect and report on all theatres of Philadelphia, as was done by a similar committee of the Citizens' Association of Chicago, but on due consideration doubted whether it was vested with sufficient power by the Institute to carry this plan into effect.

Your committee in closing its report cannot help referring to two most necessary factors in reforming our theatres. (1) The education of the public on this subject by popular lectures, articles and papers: and (2) the co-operation of prominent mechanics and scientists. While the mechanical engineer of to-day, through the arm of a child, moves enormous loads by his hydraulic cranes, the numerous hoisting apparatuses of the stage are of a truly pitiable simplicity.

The problem of building theatres properly, is eminently one of the mechanical engineer, and will never be solved if the technical resources of our age are not taken into account, and brought to bear on the question.

C. John Hexamer, C. E.
Thomas Shaw, M. E.
Henry R. Heyl.

Minority Report.

Philadelphia, April 18th, 1883.

The undersigned heartily approves all of the foregoing except the thirty-second recommendation, page 438, for a smoke flue above the stage, and that portion on the same page which refers to the work of the Asphaleia, concerning which he has no personal knowledge. He considers a smoke flue above the stage as in the highest degree dangerous, and calculated to increase the draft and strengthen the flames, producing a general conflagration instead of a local blaze.

Robert Grimshaw.

Imitation Caoutchouc.—Dankworth and Landers, of St. Petersburg, have invented a composition which is elastic, tough, waterproof and insulating, and which is applicable to nearly all the purposes for which India rubber is used. It is composed of a mixture of wood and coal tar, linseed oil, ozokerit, spermaceti and sulphur, which are thoroughly mixed and heated for a long time, in large vessels, by means of superheated steam.—*Ackermann's Gewerbezeit'g.* C.

THE SECOND LAW OF THERMO-DYNAMICS.

By H. T. EDDY, PH.D., University of Cincinnati.

Professor De Volson Wood has, in the May number of this Journal, attempted to show the geometric and mechanical impossibility of the process I have suggested for interfering with the ordinary exchanges of radiant heat between bodies. His mistake is in substituting a mill of his own invention for mine, and different from mine, and then showing that his mill will not work, as it certainly will not. In constructing his mill he has evidently placed his reflectors *c*, at right angles to the path of the ray. But I have made no such assumption in regard to the proposed position of my reflectors, for I say on the first page of my original article: "Let the surface of *c* which faces *b* be perfectly reflecting, and let the parts between its apertures be either concave or a series of inclined planes so directed that each of the projectiles will pass back through one of the apertures in *b*." Is it denied that they can be so directed? They certainly can be so directed, even though "the apertures are so placed that *a*, *c*, *b*, are upon one (and the same) straight line," as I have stated them to be, instead of being upon different lines, as Professor Wood has placed them.

That this inclined position of the reflectors is contemplated all through my paper is seen also from a sentence on the page next to the last, where I say that the "vanes (of the screen *c*) may be so inclined as to return radiations coming from *B* partly to apertures in front of those from which they emanated and partly to those behind." In fact, the very proof on which Professor Wood relies to show that his mill will not work, demonstrates beyond doubt that my mill will work, for the part of his mill which stops radiations from *A* is just where I have an aperture to allow them to pass.

Change of Volume in Galvanizing.—E. Bouty has found by recent observations that the variations of volume in galvanic deposits, which exercise a pressure upon the moulds, and the Peltier phenomenon at the surfaces of contact, are mutually connected. He finds a certain intensity of current, which he calls the neutral point of temperature. In all higher intensities the electrode heats, and in lower intensities it cools, during the process of deposition.—*Comptes Rendus.*

ON THE PRESENT CONDITION OF THE SODA INDUSTRY.

By Walter Weldon, F.R.S.

[Abstract of a paper read before the Society of Chemical Industry, January 8, 1883.]

About a fortnight ago the *Times* spoke of the manufacture of soda by the Leblanc process as being, "to some extent, a dying industry." Although I hope to show this evening ground for believing that that industry is not going to die just yet, it has certainly for some time past been in a condition by no means satisfactory to the greater number of those whose capital is engaged in it. For manufacturers of soda, by the Leblanc process, recent years have been years in very many cases of loss, and in not a few cases, of disaster. Of twenty-five alkali works which were in operation in the neighborhood of Newcastle-on-Tyne a very few years ago, only thirteen are in operation now; and of the other twelve* not fewer than eight have been actually dismantled, in utter dispair of its ever again being possible to manufacture soda in them by the Leblanc process, except at an absolute loss. The alkali-making districts of Lancashire have advantages over the Newcastle district in respect alike of the price of salt, of facilities for supplying the American market, and of nearness to certain of the great English centres of soda consumption; but, nevertheless, even in Lancashire some seven or eight alkali works are standing idle, and but few of the others are working up to their full capacity. In Belgium, where there are five or six works which formerly made soda by the Leblanc process, matters are even worse, since in that country the manufacture of Leblanc soda has entirely ceased. The only other European countries in which the soda industry as yet exists are France, Germany and Austria.

From information kindly supplied to me by manufacturers in all the countries in which the soda industry is practised, I have been enabled to draw up a statement of the present total soda production of the world, and of the proportions in which that production is divided between the Leblanc process and the ammonia process. In drawing

* The quantity of salt decomposed in these twelve works was about 67,000 tons a year. The quantity decomposed in the thirteen works still in operation is about 220,000 tons a year.

up the following table, I have converted all the figures supplied to me, alike those for soda ash, those for crystals, those for caustic soda, those for bicarbonate, and those for black ash sold as such, into terms of pure Na_2CO_3:

PRESENT SODA PRODUCTION OF THE WORLD.

	Leblanc soda.	Ammonia soda.	Totals.	Ammonia soda per cent. of total soda.
Great Britain	380,000	52,000	432,000	12·0
France	70,000	57,125	127,125	44·9
Germany	56,500	44,000	100,500	43·8
Austria	39,000	1,000	40,000	2·5
Belgium	....	8,000	8,000	100·0
United States	....	1,100	1,100	100·0
Total	545,500	163,225	708,725	23·0

This table shows that the total quantity of soda now being manufactured annually is nearly 710,000 tons, and that of this quantity more than 163,000 tons are produced by the ammonia process.

Although it is now more than forty-seven years since the ammonia process was first proposed by Dyer and Hemming, it is less than seventeen years since that process was first realized industrially. As an industrial process, capable of being worked continuously and with satisfactory commercial results, the ammonia process dates only from 1866, being the year in which M. Ernest Solvay, of Brussels, began to produce ammonia soda at works which he had established for the purpose at Couillet, near Charleroi. M. Solvay has now two other ammonia soda works in operation,—one in France, at Varangeville-Dombasle, near Nancy, and one in South Germany, at Whylen, in the Grand Duchy of Baden,—and by his courtesy I am enabled to place before you the following statement of the quantities of ammonia soda which he has manufactured in each complete twelve months from May 1st, 1866:

	Tons.	
1866–67	179	Couillet only.
1867–68	465	
1868–69	719	
1869–70	940	
1870–71	1,862	
1871–72	2,805	
1872–73	3,423	
1873–74	3,980	
1874–75	4,678	
1875–76	5,768	Couillet and Dombasle.
1876–77	11,579	
1877–78	19,247	
1878–79	25,023	
1879–80	32,326	
1880–81	42,669	Couillet, Dombasle, and Wyhlen.
1881–82	53,400	

These figures come down to the 30th April last. Since that date, however, M. Solvay has increased his production by nearly 60 tons per day, or 21,000 tons per annum, so that he is now making ammonia soda at the rate of nearly 75,000 tons a year. He is thus making ammonia soda on nearly three times the scale on which he was making it four years ago, and on nearly twice the scale on which he was making it only two years ago. In France and Germany, M. Solvay's great success has tempted other manufacturers into the field, and although none of them are as yet large makers, their total production amounts to fully 35,000 tons per annum, raising the total Continental production of ammonia soda to about 110,000 tons per annum, out of a total production by both processes of 275,000 tons. Of the total soda now being made on the Continent, therefore, about forty per cent. is being made by the ammonia process. While the quantity of Leblanc soda made in France has neither increased nor diminished during the last few years, the quantity of Leblanc soda made in Germany and Austria has increased by several times the quantity formerly made in Belgium, so that not only these 110,000 tons of ammonia soda per annum, but also fully 25,000 tons per annum of Leblanc soda, have been added, comparatively recently, to the soda production of the Continent; going partly to supply increased consumption, but largely to diminish importation from England. And of this vast increase in the Continental production of soda, four-fifths of which increase is due to the ammonia process, two-thirds have

sprung into existence within the last five years, and a large part of those two-thirds within only two years.

In England, within the last two years, the production of ammonia soda has been nearly trebled. The ammonia process is practised in this country as yet only by one firm. In 1873 it was not in operation in this country at all. In that year our Honorary Foreign Secretary, Mr. Ludwig Mond, arranged with M. Solvay for the right to work under his patents in this country, and in the following year, in conjunction with Mr. J. T. Brunner, Mr. Mond began to make ammonia soda at Winnington, near Northwich. Messrs. Brunner and Mond began on a very modest scale, their production in 1875 not exceeding 2,500 tons; but in 1878 their production rose to 10,000 tons; in 1880 it was 18,800 tons; and it is now at the rate of not less than 52,000 tons per annum, or at very nearly three times the rate of only two years ago.

The competition of the ammonia process with the Leblanc process has thus attained its present degree of seriousness only very recently indeed. It has come upon the makers of Leblanc soda almost like a thunderbolt out of a clear sky.

And, serious as that competition is already, it is about to become even more serious still. Not only is it to be expected of the existing ammonia soda works that those of them which have recently so greatly increased their production, and that those of them which have more recently started will grow as the older ammonia soda works are being built. M. Solvay, who has already, as I have said, a work in operation in South Germany, besides his French and Belgian works, and who is already by far the largest soda maker in the world, will soon have a work in operation in North Germany also, at Bernburg, near Stassfurt; and he is now, moreover, erecting a work in Russia, and also a work in the United States, and is on the point of commencing the erection of a work in Austria, so that by-and-by he will be making soda in no fewer than seven distinct works, in six different countries. In addition to all this, a large work to make ammonia soda, not on M. Solvay's system, but on a system modified from that practised at Dieuze, is being erected near Stassfurt by the Company of Buckau; an ammonia soda work is building, and will be started in the spring, at Favorznow, near Cracow; and one is about to be built at Siebenburgen, in Transylvania, not to speak of the intention of Messrs. Bell Brothers to build an ammonia soda work at Middlesbrough. The

new works which are thus in course of construction, and some of which are nearly completed, will throw on the market more ammonia soda, to the extent of not less, from the commencement, than from 65,000 to 70,000 tons a year.* For Leblanc soda makers it is thus as though ammonia soda had latterly rained from the skies during two days out of every three, and the shower were now on the point of becoming continuous.

While face to face with so serious an amount of competition, actual and imminent, on the part of the ammonia process, the Leblanc process pure and simple is now further threatened with what is surely the "most unkindest cut of all," namely, with competition from the Leblanc process itself, combined with the extraction of copper from Spanish pyrites.

To explain how this has come about, I must remind you that the sulphuric acid used in the Leblanc process is now invariably manufactured from the sulphur of pyrites; that the pyrites used in this

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* As no complete list of ammonia-soda works has yet been published, it may be interesting here to give one. The following list includes all the works now actually in operation:

England:
- Winnington,
- Sandbach.

Germany:
- Wyhlen,
- Duisburg,
- Inowrazlaw,
- Grevenberg,
- Dieuze,
- Trotha,
- Heilbronn,
- Nürnberg,
- Rothenfelde.

France:
- Dombasle,
- Giraud,
- Sorgues,
- St. Denis,
- Lille.

Belgium:
- Couillet.

Austria:
- Boszko.

United States:
- Bay City.

Ammonia-soda works are now being built in the following localities:

Austria:
- Favorznow,
- Siebenburgen.
- ?

Russia:
- Berenski.

Germany:
- Stassfurt,
- Bernburg.

United States:
- Syracuse.

There is a reason why the locality of the works about to be built by M. Solvay, in Austria, may not yet be published.

country is now almost exclusively either Spanish or Portuguese pyrites, containing two or three per cent. of copper and very small quantities of silver and gold; that after most of the sulphur has been burnt off from the pyrites, as the first step in the manufacture of sulphuric acid, the residual "burnt ore," or "pyrites cinders," as it is called, is treated by the wet way for the extraction from it of copper, and in most cases now of gold and silver also;* and that what remains when these have been extracted is an almost pure oxide of iron, which finds a ready sale for use for various purposes in connection with the manufacture of iron and steel. The supply of this cupreous pyrites is for the most part monopolized by three great companies,—the Tharsis Company, the Rio Tinto Company, and Messrs. Mason and Barry. These companies not only supply nearly the whole of the pyrites used in the manufacture of sulphuric acid in England, but the Rio Tinto Company also supplies annually some 60,000 tons of pyrites to Germany, and is also beginning to send pyrites into Austria. None of the three companies, however, has been able to sell an ounce of pyrites in France.

The reason of this is that in France itself there are two large deposits of pyrites, both belonging to soda makers: one belonging to the Compagnie de St. Gobain and the other to MM. Pechiney et Cie. Each of these companies itself uses its own pyrites; and the former of them supplies with pyrites the greater number of the other alkali makers in the North of France, while the latter supplies with pyrites all the other alkali makers of the South of France. It has obviously been impossible to sell Spanish pyrites to either of the two great soda making firms, each of which thus has pyrites, and by no means dear pyrites, of its own, and each of which is a large seller of pyrites to other soda makers; and the other soda makers, for the most part, have been precluded from even considering the question of changing to Spanish pyrites, if only by reason of the French habit of contracting for the supply of raw materials over very long periods. A French manufacturer's contract for raw materials is generally a contract for fifteen years; and most of the French soda makers are now obtaining

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* A German analysis of Rio Tinto pyrites gives the following results per 1,000 kilos:

495 kilos. sulphur.	26 grammes silver.
430 kilos. iron.	180 miligrammes gold.
30 kilos. copper.	150 grammes bismuth.
10 kilos. lead.	

their pyrites under contracts which have yet a considerable time to run.

Under these circumstances the Rio Tinto Company has taken a remarkable step. To understand the motive to this step it must be borne in mind that while French pyrites does not contain copper, and so has scarcely any value beyond that of the sulphur which it contains, Spanish pyrites has a considerable value in addition to its sulphur value. While the value of Spanish pyrites for the sulphur in it is equal to that of the best non-cupreous pyrites, its value for copper is greater than its value for sulphur, and, not to speak of its value as regards precious metals, it has also a considerable value for its iron. In this country, the cinders left after as much as possible of the sulphur of non-cupreous pyrites has been burnt off, are considered to have no value at all; and even in France, where the import duty on cast iron is greater than the present price of Glasgow pigs, and where all forms of iron are therefore appreciably more valuable than in this country, the cinders of non-cupreous pyrites are not worth more than 3f. per ton. They always contain sulphur, and sometimes contain phosphorus. The cinders of cupreous pyrites, before treatment for the extraction of copper from them, also contain sulphur, and in larger quantity than the cinders of non-cupreous pyrites; but the treatment to which they are subjected for the extraction of their copper removes the whole of their sulphur, and also the whole of their phosphorus, if they have contained any, leaving a residual oxide of iron of great purity. This residual oxide, or "purple ore," as it is called, now sells in this country for 12s. per ton, and in France it would doubtless command a higher price.

Now, in this country a state of things has grown up under which the manufacture of Leblanc soda derive no advantage from the value for copper and iron of the pyrites which they employ. The treatment of the cinders of the cupreous pyrites has become in this country a separate industry, practised only in a few instances by alkali makers themselves, but practised for the most part by companies or individuals who do not make soda, but who either buy from soda makers the cinders or pyrites of which the soda makers have bought both values, the copper value as well as the sulphur value, or themselves buy both values, selling only the sulphur value to the soda makers, or else buy direct from the pyrite sellers the copper value only; the pyrite sellers in such cases selling the copper value of their pyrites to one purchaser

and its sulphur value to another. It is an industry which yields fair commercial profits, so that soda makers may be incurring actual loss, while those who deal with the cinders of the pyrites from which the soda makers have burnt off sulphur are at least making a living. And while the treatment of the cinders of Spanish pyrites is fairly profitable in this country, the greater value of iron and iron ores there than here would doubtless render it more profitable in France. It is true that coal is more costly in France than in England; but the quantity of coal required for treating pyrite cinders is not great.

The course, then, which the Rio Tinto Company is taking is this. Unable to sell its pyrites to the French Leblanc soda makers, it has determined that the Leblanc soda made in France, or at least a large part of it, shall nevertheless be made by means of Rio Tinto pyrites, and to this end it has promoted a subsidiary company, "La Compagnie d'Exploitation des Minerais de Rio Tinto," which company is to make Leblanc soda in France and elsewhere, relying for its profits neither on soda nor on chlorine, but on copper and oxide of iron. For this company soda and chlorine will be simply by-products, which it will be glad to sell at a profit, if that may be, but which, if that may not be, it will be content to sell at the bare cost of manufacturing them. It will manufacture them only for the sake of converting Rio Tinto pyrites into pyrite cinders.

This new company proposes to operate upon an enormous scale. It has a capital of £1,200,000 sterling, of which one-half is already paid up, and there is talk of its building in France no fewer than five great works; one of which, designed and to be managed by Englishmen, it has already commenced in the neighborhood of Marseilles. The result cannot but be grave for the existing French Leblanc soda makers, and must inevitably affect the makers, both of Leblanc soda and of ammonia soda, in this country also.

Moreover, this new company will not confine its operations to France. Not only will it take Spanish pyrites to the United States, and there make sulphuric acid, extract copper, and obtain "purple ore," large quantities of which at present go from England to America, but it will also build a large soda-making and copper-extracting works, which will certainly affect the English alkali trade, in the neighborhood of Antwerp. The Leblanc process will thus be reintroduced into Belgium, not as a substantive process, but simply as a part of a combination of processes for the utilization of cupreous pyrites.

To such complexion has the Leblanc process come at last. Originally, soda was its only commercial product, the hydrochloric acid produced during the first stage of it being turned to no account. In time a demand grew up for chlorine, that hydrochloric acid began to be utilized, and the manufacturers of Leblanc soda now sent into the market two products, by each of which they gained profits. Then their soda ceased to be profitable, and became a kind of by-product, which they continued to make only because they could not otherwise make chlorine. Now, Leblanc soda gives no profit at all, and chlorine none to speak of; and both have come to be regarded as secondary products, to be made only incidentally, and only because making them is essential to the application to certain ores of the wet method of extracting copper.

Returning to the ammonia process, when that process first began to threaten them, the makers of Leblanc soda comforted themselves by two considerations; one of which was that the ammonia process must itself tend to check its own extension, by reason of the loss of ammonia inseparable from that process so increasing the demand for ammonia as to materially raise the price of that body. They knew that the constantly-increasing demand for ammonia for the purposes for which it was already employed had doubled its price within twenty years; and they thought that every further extension of the ammonia soda process must still further increase the market value of ammonia, until at length the ammonia process would cease to have any advantage over the Leblanc process. So far, however, from that anticipation having been realized, despite the immense extension which the ammonia soda process has recently undergone, the price of ammonia is now beginning to fall. The delusion that it was impossible to collect the ammonia given off from coke ovens without spoiling the coke is at last giving way before accomplished facts. Ammonia is now being obtained commercially, not only from coke ovens, but also from another source, wholly unforeseen and unexpected; and the time, moreover, seems at last to have dawned when there will be collected and utilized as ammonia at least a portion of nitrogen of nearly all the fuel burnt either for industrial or for domestic purposes. In France ammonia has been collected from coke ovens for a number of years past.

Some months ago, a member of the firm of William Baird & Co., who happens to be also a director of a gas work, Mr. William Ferrie, was struck by the idea that the methods employed for separating

ammonia and tar from crude illuminating gas might be used for separating the same bodies from the gases from blast furnaces in which raw coal is used; and although the volume of the gases from such furnaces, per ton of coal employed, is about thirteen times greater than that of the gases obtained by distilling the same kind of coal in retorts, is not less, that is to say, than 130,000 cubic feet, Mr. Ferrie's idea has been put into execution with complete success. From two of the sixteen blast furnaces at the Gartsherrie iron works ammonia and tar have been regularly collected for some months past, and the preparations are in progress for collecting them from the other fourteen blast furnaces there. The quantity of ammonia at present being obtained at Gartsherrie is the quantity corresponding to about 18 cwt. of ammonium sulphate per day, being at the rate of 20 lb. of ammonium sulphate per ton of coal consumed.

Each of the one hundred and twenty Scotch blast furnaces consumes, on an average, fifty tons of coal per twenty-four hours. The total quantity of coal consumed in them per annum is thus $50 \times 120 \times 365 = 2{,}190{,}000$ tons. The quantity of ammonia yielded per ton of coal being, as I have said, the quantity corresponding to 20 lb. of ammonium sulphate, there can thus be obtained per annum from these one hundred and twenty blast furnaces a quantity of ammonia corresponding to nearly 20,000 tons of ammonium sulphate, worth, at the present selling price of that commodity, not less than £400,000.

Large, however, as is this quantity, it is only one-tenth of the further quantity which can be obtained from English coke ovens. The quantity of coal coked annually in England is not far short of 20,000,000 tons, and if Mr. Jameson's system were applied to the whole of our coke ovens, with the result of collecting, per ton of coal treated, the same quantity of ammonia as is obtained from the Gartsherrie blast furnaces, there would be obtained from this source per annum the quantity of ammonia corresponding to 180,000 tons of ammonium sulphate, at present worth more than three and a half millions sterling. Nor is even this all; for I shall have to speak in a moment of another possible, and I believe probable, source of ammonia, even more extensive still.

Now of the ammonia employed by the ammonia soda maker, he loses from one-fiftieth to one-fortieth part. As he has to employ from one and a half to one and three-quarter equivalents of ammonia for each equivalent of sodium carbonate finally obtained, we may take it

that he loses about one twenty-third of an equivalent of ammonia for each equivalent of sodium carbonate manufactured. In terms of ammonium sulphate, being the terms in which the loss of ammonia in the ammonia soda process is usually stated, this loss corresponds to about five and a half parts of ammonium sulphate per hundred parts of sodium carbonate produced. The total annual loss of ammonia in the manufacture of the 163,000 tons of ammonia soda now being produced per annum thus corresponds to just about 9,000 tons of ammonium sulphate. This is, no doubt, a large quantity of a commodity worth £20 per ton; but, in comparison with the extent of the new sources of ammonia which have just began to be turned to account, it is utterly insignificant. It is less than one-twentieth part of the quantity capable of being yielded by blast furnaces and coke ovens in Great Britain alone, and is a smaller fraction still of the quantity which, I believe, can be obtained from another source which has yet to be mentioned. We may therefore be quite certain that the progress of the ammonia soda process will not be hindered or limited by any difficulty as regards supply of ammonia.

The other consideration to which I referred as having given comfort to the makers of Leblanc soda, and which constituted indeed their chief ground of hope for salvation against the ammonia process, was that the world requires chlorine as well as soda, and that while the chlorine of the salt decomposed by the Leblanc process is yielded as hydrochloric acid, from which free chlorine can be obtained readily, the chlorine of the salt decomposed by the ammonia process is yielded as a somewhat dilute solution of calcium chloride. It was thought that the ammonia process would eventually even help the existing Leblanc soda makers, by preventing the further extension of the Leblanc process, and so restricting the production of hydrochloric acid, and thereby at length increasing the value of that body. The ammonia process, no doubt, would have produced that result, and would have produced it by this time, if the supply of hydrochloric acid in this country had not been already so largely in excess of the demand for chlorine products. That demand is always becoming larger, and within the last few years the production of hydrochloric acid has appreciably diminished; but in this country the constantly-increasing stringency of legislative enactments with respect to river and air pollution has compelled so many producers of hydrochloric acid, who would have preferred to throw their acid away, to employ it

in the manufacture of chlorine, whether that manufacture were profitable or not, that the selling price of chlorine products has of late years been continually falling, until it is now at a point at which it barely pays their cost. No doubt if all the other conditions of the problem were to remain as at present, the demand for chlorine products would in time overtake the supply of hydrochloric acid in this country, as it has long since done on the Continent, and the manufacture of chlorine in England would so again become prófitable. But the other conditions of the problem are not likely to remain stationary, and both M. Solvay and myself are doing our best to change them.

M. Solvay is proposing to manufacture hydrochloric acid from the residual calcium chloride of the ammonia process. I imagine that he is urged to that course, not merely by a desire to turn that calcium chloride to account, but also by a desire to avoid making too much nuisance. For it must not be supposed that even the ammonia process, when practised on a large scale, is free from nuisance. It certainly does not send into the air any noxious vapors, but it sends into the water courses very large quantities of calcium chloride, rarely accompanied by less, and often accompanied by much more, than an equivalent quantity of sodium chloride, and very apt to be accompanied also by both calcium carbonate and free lime. Neither calcium chloride nor sodium chloride will do much harm to a river, if sent into it in moderate quantities; but when it comes to sending into a comparatively small stream, far inland, two hundred and sixty tons of calcium and sodium chlorides per twenty-four hours, say about ten tons per hour, night and day, all the year through,—and M. Solvay must be doing something very like that at Dombasle,—the matter assumes quite another aspect. I am not myself an angler, but if I were, I do not think that I should seek for sport immediately below Dombasle.

Be all that however as it may, M. Solvay is now erecting at Dombasle apparatus for an industrial trial of a process for obtaining hydrochloric acid from calcium chloride, at which he has been working for many years. The process in question consists in first concentrating by evaporation the mixed solution of calcium and sodium chlorides which is the residual product of the ammonia process; then mixing the concentrated solution with clay, making the mixture into balls, and drying these balls; and then heating these balls to redness in a current of steam. This process certainly works, on condition that the temperature employed be sufficiently high, and that the quantity of steam used be

largely in excess of the quantity necessary to react upon the calcium chloride. As the resulting mixture of vapor of water and vapor of hydrochloric acid would otherwise give an extremely dilute aqueous acid, M. Solvay proposes to separate from it most of its vapor of water, before condensing its hydrochloric acid, by passing the mixture of the two vapors through a very strong solution of $CaCl_2$, which he finds will absorb most of the steam from such a mixture, allowing the HCl to pass on alone, so that it can afterwards be condensed in the usual way. All this is ingenious, but it can hardly be cheap. First, a solution containing only about eight per cent. of calcium chloride has to be evaporated, we may say to dryness; then the mixture of $CaCl_2$ and clay has to be maintained at a red heat for a considerable time, in a current of steam; and then the solution of calcium chloride used to separate steam from the resulting mixture of steam and HCl has to be prepared for use again by having all the water which it has absorbed evaporated off from it. To English manufacturers who have more hydrochloric acid than they can use, this process of M. Solvay's will seem little less than ridiculous; but one must remember that it is intended for countries in which the demand for hydrochloric acid exceeds the supply, and in which countries, moreover, chlorine products are protected by import duties. In such countries, one can quite conceive its being commercially practicable; in which case the exportation of chlorine products from England to the Continent is doomed. I ought to add that M. Solvay expects that the silico-aluminate of calcium which remains after the chlorine of his mixture of calcium chloride and clay has been driven off by steam will be useful as a cement, and will thus help to pay the cost of his hydrochloric acid.

The exportation of chlorine products from England to the Continent is, moreover, threatened in another way. The Continental manufacturers of Leblanc soda, unlike the English manufacturers of Leblanc soda, do not produce enough hydrochloric acid to meet the demand of their respective countries for that acid itself, and the products which are made from it. This is partly due to the production of ammonia soda, proportionately to the total production of soda, being so much greater in France and Germany than in this country, and partly to hydrochloric acid being required in those countries for industries which in this country do not exist. Large quantities of chlorine products consequently go to the Continent from this country; our production of hydrochloric acid being still sufficient to enable us to supply,

not only the total English demand for chlorine and the total American demand for chlorine, but also an appreciable proportion of the Continental demand for chlorine, and, in addition to all that, to throw a large residue of hydrochloric acid into the North Sea. The Continental Leblanc soda makers do not like this importation into their respective countries of chlorine products from England; but they can prevent it only in one or other of two ways; either by increasing their production of hydrochloric acid, or by becoming enabled to obtain from a given quantity of hydrochloric acid a larger proportion of free chlorine than is yielded by the process at present in use. Personally, I have for the process at present in use that respect which one always feels for the bridge which has carried one over, but I am well aware that it can by no means be regarded as final. It yields chlorine cheaply; but it yields only one-third of the total chlorine contained in the acid employed, the other two-thirds being lost as calcium chloride. English chlorine manufacturers will regard almost with horror the idea of a new chlorine process which shall yield in the free state practically the whole of the chlorine contained in the acid employed; but on the Continent there is a demand for such a process; a demand which will no doubt be lessened, but will by no means be destroyed, by what is being done in France by the Compagnie d'Exploitation, and I am one of those who have been called upon to endeavor to supply that demand. M. Pechiney is now preparing to make, at Salindres, a trial on an industrial scale, of a process which, I think, will supply it; and by the end of this year he will probably have obtained decisive results.

As regards the English chlorine industry, however, I do not think that its prospects are by any means so gloomy as, from what I have said so far, might at first blush appear. But I think that its salvation will come from an unexpected quarter. I think that our English manufacturers of Leblanc soda will have to cease to devote their hydrochloric acid, when they do not throw it away, exclusively to chlorine making. They would, of course, be only too glad to do so, if a means could be furnished them of turning it to account otherwise. But the difficulty hitherto has been as to how to turn it to account otherwise. I believe that that difficulty is about to disappear. I am not free to enter into that matter now, and, indeed, it is not yet ripe for discussion; but I have very great confidence that new applications of hydrochloric acid, admitting of being applied very extensively, at

comparatively small expense, are among the things of the immediate future.

As regards soda, the position of the English Leblanc soda makers is this. They are now working, when not actually at a loss, at least without profit. Until comparatively recently, they supplied the whole of the English demand for soda, the whole of the American demand for soda, and a large part of the Continental demand for soda. Both their home market, however, and their American market have been recently invaded by English made ammonia soda, and now the manufacture of ammonia soda has begun in the United States themselves, and will have reached there before the expiration of this year, a scale of 20,000 tons per annum; while a little later on that Belgian soda and copper work of which I spoke, will not only have put an end to all export of English soda to Belgium, but will doubtless also be sending Leblanc soda to America; as will also, no doubt, the great work which is being built at Marseilles, and, eventually, those other works which are about to be built at others of the French seaports. The exportation of English soda to Austria, which has already dwindled to little more than 8,000 tons per annum, is expected to cease entirely before the end of the present year, by reason of the increased quantity of ammonia soda which will soon be made in Austria. An increased production of ammonia soda is similarly expected to put an end, almost immediately, to the importation of English soda into Germany; which importation, in 1881, was already only two-thirds of what it was in 1879. Russia, moreover, will soon be making for herself at least a portion of the soda she consumes; and France, which country has hitherto been entirely dependent upon England for her supplies of caustic soda, though she has long ceased to take from us any other form of soda, will soon be making, herself, all the caustic soda she requires; for, apart from what may be done by the new company of which I have spoken, M. Solvay is just beginning to make caustic soda at Dombasle, and contemplates making it there on a very extensive scale.

In face of all this, how are the English Leblanc soda makers to continue to live? For one thing, it is quite certain that they must have cheaper pyrites. The present price of 6d. per unit is an artificial price, entirely due to a trade combination; and that price will certainly have to be reduced by at least fifty per cent. That it can be reduced to 3d. per unit, and yet leave a very fair profit to the pyrite

sellers, I believe there can be no doubt. At the present price of copper, and at 3d. per unit for sulphur, pyrites showing 2½ per cent. of copper by Swansea assay, would sell for 39s. per ton; and that Spanish pyrites can be delivered to English ports at that price, at a fair profit is, I believe, unquestionable. If, therefore, the existing companies refuse to supply pyrites at that price, they will simply call into existence other companies which will supply it at that price. That the Leblanc soda makers will thus get their sulphur at a price not exceeding 3d. per unit, after the end of next year, when the present combination between the pyrite companies will expire, may be regarded as quite certain.

Pyrites at 3d. per unit, however, would by no means bring down the cost of Leblanc soda to that of ammonia soda. Without using any figures which have been given to me privately, there is no difficulty in arriving, very approximately, at the difference between the cost of ammonia soda and that of Leblanc soda, from what is matter of public knowledge with respect to the dividends paid by joint stock companies which make ammonia soda, and publish balance-sheets. We learn in this way, that when Leblanc soda is yielding no profit at all, ammonia soda is yielding fully £1 per ton. As to make a ton of actual sodium carbonate by the Leblanc process does not require more than about 13·5 cwt. of pyrites, reduction of the price of pyrites to 3d. per unit would thus reduce the cost of Leblanc soda only by about 7s. 9d. per ton of actual sodium carbonate.

Seven shillings and ninepence, however, is something; and, as regards the balance of the pound, there are two resources, which together will, I think, be sufficient to turn the tables upon the ammonia process, and make the good old Leblanc process the cheaper of the two.

One of these two resources consists, of course, in sulphur recovery. If sulphur recovery were the only resource, which, however, happily it is not, I think it not impossible that the required 12s. 3d. per ton of sodium carbonate could be gained by it alone. To this end, except in localities in which there is a demand for sulphuric acid free from arsenic, the sulphur must be recovered, not as sulphuric acid for use again, but as free sulphur, for sale as such. At the general meeting of our Society at Manchester, last July, I explained that, while the Schaffner and Helbig process would yield as sulphuric acid practically the whole of the sulphur of the calcium sulphide contained in the

waste treated by it, it would probably yield as free sulphur only four-fifths of the total sulphur contained in the waste as calcium sulphide. Since then, reason has arisen for a very confident hope that the whole of the sulphur of the calcium sulphide contained in the waste may be obtained in the free state; in which case the yield will be almost exactly 6 cwt. of free sulphur per ton of actual sodium carbonate manufactured. If, therefore, one were dependent for that 12s. 3d. on sulphur recovery alone, the problem would be narrowed to this: Can free sulphur be obtained from alkali waste at such a cost, and is there a sufficient demand for free sulphur at such a price, that it shall be possible to sell recovered sulphur, in sufficient quantity, at 2s. 0½d. per cwt., or say 41s. per ton, more than the cost of producing it?

As regards the demand for free sulphur, the latest returns published by the Italian government show that the average annual production of sulphur in Sicily and Italy, during the five years 1875 to 1879, inclusive, was 282,000 tons, of which 216,000 tons were exported. The total quantity of sulphur that could be produced from English alkali waste does not exceed two-thirds of this latter quantity. The world thus consumes much more sulphur than the English alkali makers could produce, and although to sell all that they could produce they must drive much of the Sicilian sulphur out of the market, in the present "struggle for existence" somebody must go down, and English Leblanc soda makers may be pardoned for preferring that it should be producers of Sicilian sulphur who have to do so rather than themselves.

The actual cost of Sicilian sulphur, delivered at Marseilles, transported in the cheapest way, in bulk, at the purchaser's risk, is about £5 per ton. To become masters of the sulphur market, and at the same time to gain by recovered sulphur the required 2s. per cwt., English soda makers must thus be able to recover sulphur at a cost not exceeding, say about £2 per ton. They will hardly be able to do that at first, but I think that eventually they will be able to do it. If so, and if chlorine products should again command, as I think they will again command, a reasonable price,—for a price which scarcely pays their cost, is, of course, not a reasonable price,—the Leblanc process will at least be able to hold its own, even without that other resource to which I have referred, and which I will now proceed to indicate.

There has come to me from Newcastle a very bold, but, I venture to think, quite practical suggestion, the result of which can hardly fail

to be of enormous importance, not only to the soda industry, but to almost all industries whatever. That suggestion is that the soda maker should entirely cease to use raw coal as fuel, but should convert all his coal into coke, collecting for sale the oil and ammonia evolved during its conversion into coke, and himself using for heating purposes the gases evolved during the coking operation and the coke itself. It is believed, that in the Newcastle district at any rate, by this mode of proceeding the soda maker would obtain his fuel virtually for nothing. In that district there is produced per annum some two millions of tons of very small coal or "duff," which is almost a waste product, and which, singularly enough, yields more oil than the more costly kinds of Newcastle coal, while at the same time yielding a very fair coke, sufficiently good, at any rate, for use in the furnaces of chemical works, especially when its combustion is assisted by that of the gases from the ovens in which the coke is produced; and the value of the oil and ammonia obtained when this "duff" is coked in ovens to which the Jameson system is applied is greater than the cost of the "duff," *plus* the cost of coking it. And it is probable that improved condensing arrangements will render the yield, if not of oil, at any rate of ammonia, so much greater than the yield hitherto actually realized, as to enable the same result to be obtained in the case of ordinary steam coal, not only in the Newcastle district, but in the Lancashire district also. If so, the cost of producing Leblanc soda in both districts will be diminished by almost the total amount of the present cost of Leblanc soda for fuel. I say "almost," because, so far as one can see, the use of raw coal for "mixing" in the black-ash process must still be continued.

And it seems to me that this idea cannot but be as applicable to almost all other industries as to the soda industry, while the result to the material well-being of mankind of its general application, it is utterly beyond the power of any imagination adequately to conceive. This idea means, among other things, cheaper fuel for all purposes, an enormously increased supply of agricultural produce, and the entire suppression of smoke, even in the busiest centres of industry.

And for my own part I venture to think that the same idea might be applied even to the fuel required for domestic purposes, rendering London absolutely free from smoke, and pea-soup fogs, things only of tradition. I think that the time will come when our gas works will be replaced, at least to a large extent, by establishments in which coal

will be treated for the production of coke, illuminating oils, ammonia, and heating gases, the coke to be burnt in our domestic fire-places, the oils to be used for lighting the interiors of our houses, the ammonia to be employed in agriculture, to cheapen and render more abundant our supplies of food, and the gases to be burnt for raising steam for driving dynamos for lighting our streets by the electric arc.

Coming back to soda. If the suggestion in question will enable makers of Leblanc soda in certain districts, to obtain their fuel for nothing, it will, of course, enable makers of ammonia soda, in similar districts, to do the same. How then will it help the Leblanc soda makers? While the quantity of fuel consumed in the ammonia process is only 150 per cent. on the soda produced, the quantity consumed in the Leblanc process is about 350 per cent. on the soda produced. This lower consumption of coal in the ammonia process than in the Leblanc process has hitherto been one of the chief advantages of the ammonia process; but fuel for nothing will so far convert this advantage into a disadvantage that it will reduce the cost of ammonia soda per ton only by the cost of one and a half tons of fuel, while it will reduce the cost of Leblanc soda per ton by the cost of fully twice that quantity of fuel. No doubt this result will be accompanied by some diminution in that heavy item in the cost of ammonia soda which is due to loss of ammonia; but still I think that the balance of advantage will be on the side of the Leblanc process. It can only fail to be so by reason of ammonia falling to one-half of its present price. The price of ammonia unquestionably will fall; but I think that increased use of ammonia in agriculture will prevent its price falling to anything like that extent.

Here the present paper might very well have ended, but I know that it is expected by some of the members present that I should say something on the present state of the sulphur recovery question; and I have therefore to ask permission to go on a little longer in order to do so.

In order to render intelligible some interesting results relating in some degree to the commercial side of the Schaffner and Helbig process, which were obtained at Oldbury in the autumn, and which I have permission to report this evening, allow me to remind you that the two main operations of that process consist: first, in decomposing the calcium sulphide contained in alkali waste by heating the waste with solution of magnesium chloride, whereby there is obtained, on the one

hand, H_2S, and, on the other, solution of calcium chloride holding magnesium hydrate in suspension; and, secondly, in regenerating magnesium chloride for use again by treating that mixture of magnesium hydrate and solution of calcium of chloride by CO_2:

FIRST OPERATION.

$$CaS + MgCl_2 + 2H_2O = H_2S + CaCl_2 + MgH_2O_2.$$

SECOND OPERATION.

$$CaCl_2 + MgH_2O_2 + CO_2 = MgCl_2 + CaCO_3 + H_2O.$$

During the construction of their new plant, Messrs. Chance Brothers made a series of quantitative experiments, upon a scale of half a ton of waste per operation, mainly with a view to determining quantitatively the loss of magnesia involved in the process. These experiments were conducted by Mr. Frederick Chance, a young member of the firm, who has only to fulfil the promise of his youth to take a very high rank among industrial chemists, and their results are interesting and to a certain extent important. By making a number of successive operations without adding any fresh magnesia or magnesium chloride, and comparing the quantity of magnesium chloride which he had at at the end of the series of operations with the quantity which he had at the beginning, Mr. Frederick Chance found that the average loss of magnesia corresponded to 1·05 parts of MgO per 100 parts of waste treated. Now, while in the waste produced at Oldbury there is no magnesia to speak of, a very pure limestone being used there for making black-ash, there is reason to believe that the waste produced in the Newcastle district, the limestone of which district is all more or less magnesium, contains fully enough magnesia to make up this amount of loss, without the addition of any magnesium compound specially for that purpose. All that should be needed, therefore, in the case of Newcastle waste, should be to add from time to time the quantity of calcium chloride necessary to convert into magnesium chloride, by the aid of CO_2, the magnesia actually existing in the waste itself. In other cases, the loss of magnesia in the Schaffner and Helbig process might be made up by replacing two or three per cent. of the limestone used for making black-ash by dolomite. This is supposing, of course, that the calcium carbonate recovered in the process is not used again in black-ash making. In proportion as this recovered carbonate can be used again for making black-ash, there will be no

loss of magnesia; the magnesia "lost" in one operation coming round again in the next.

The experiments of Mr. Frederick Chance further brought out the important fact that the reaction by which magnesium chloride and calcium carbonate are recovered takes place, at any rate under the conditions under which he operated, *i.e.*, under a pressure of twenty pounds per square inch, quite as readily when the mixture treated by CO_2 is hot as when that mixture is cold. It has been supposed that that reaction depends upon the formation of bicarbonate of magnesia, in which case the mixture in question would have required to be cooled before being treated by CO_2, and so to cool it would have been at least troublesome. It seems, however, that the reaction in question is really a reaction between $CaCl_2$ and $MgCO_3$. This result is confirmed by the result obtained by Dr. Hewitt by simply mixing with solution of $CaCl_2$ an equivalent of the carbonate of magnesia of the shops. He obtained in that way a decomposition of about 80 per cent. of his calcium chloride, and it is probable that the carbonate of magnesia he employed did not contain more than that percentage of $MgCO_3$.

Mr. Frederick Chance further lighted upon a very curious fact, which is valuable as affording to the workmen a simple and ready indication of the moment at which the regeneration of the magnesium chloride has become complete. In the mixture operated upon there is always a little ferrous sulphide. This ferrous sulphide is not acted upon by CO_2 so long as there is any free magnesia present, but it is attacked so soon as all the magnesia present has become carbonated, with the result of sending iron into solution as acid ferrous carbonate. The presence of the iron which thus comes into solution can be very readily detected, and the moment it appears the workmen in charge know that it is time to stop injecting CO_2.

In the South of France, experiments are now being made, at my instance, with a modification of the Schaffner and Helbig process. Most of those in France who make salt from sea water content themselves with obtaining therefrom only common salt; but M. Pechiney treats the mother liquors from which as much NaCl as possible has been crystallized out for the further obtainment from them of sodium sulphate, magnesium sulphate, and potassium chloride, and his final residue is a saturated solution of magnesium chloride, containing no other body except magnesium bromide. It has seemed to me that this magnesium chloride might be utilized at once for the recovery of sul-

phur from soda waste, and as a source of magnesia for sale as such. When alkali waste, however, is treated directly by solution of magnesium chloride, the magnesium hydrate, which is one of the products of the reaction which takes place, is obtained in admixture with all the numerous bodies other than calcium sulphide, which were contained in the waste treated. When the magnesium hydrate is to be employed for the regeneration of magnesium chloride, this presence with it of foreign bodies does not matter; but in cases in which regeneration of the magnesium chloride used is not necessary, while it is desired to obtain magnesium hydrate for sale, the presence of foreign bodies with the magnesium hydrate must be avoided. I propose to avoid it by taking advantage of a reaction which is known as Kraushaar's, from its having been first published, in "Dingler's Journal," for 1877, by Dr. Kraushaar, of Thann, but which was really first discovered by Mr. Helbig, at Aussig, and turned by him to practical account there as early as 1874. This is the reaction which takes place when alkali waste is heated with water under pressure. It is a reaction of two of water upon two of calcium sulphide, giving one of calcium hydrate and one of calcium sulphydrate. The calcium sulphydrate is obtained in solution; and if this solution be separated from the calcium hydrate and other bodies which it at first holds in suspension, on then running into it a solution of magnesium chloride there is obtained, on the one hand, H_2S, and on the other, magnesium hydrate, almost chemically pure. And it is to be noted that, whereas when alkali waste is treated directly with solution of magnesium chloride, only one of H_2S is obtained for each equivalent of $MgCl_2$ which enters into reaction, by first getting the sulphur of the waste into the state of calcium sulphydrate two equivalents of H_2S are obtained for each equivalent of magnesium chloride decomposed.

At one time I had some hope that one might take advantage in England of this reaction of two of water upon two of waste to the end of reducing by one-half the quantity of magnesium chloride to be employed, and consequently the quantity of that body to be recovered, per given quantity of alkali waste treated. Mr. Chance was so obliging as to make some experiments on this point at Oldbury, and Mr. Helbig made others at Aussig, and the result of both series of experiments went to show that the idea is not applicable, or at any rate not applicable with any great advantage, when the magnesium chloride employed has to be regenerated. The reason is that the whole of the

sulphur of the calcium sulphide of the waste which is heated with water under pressure does not come into solution unless a certain minimum quantity of water be used. This quantity of water is not too great to permit of the method being employed with advantage when the magnesium chloride has not to be recovered. But when it has to be recovered all this water would have afterwards to be driven off by evaporation, or the regenerated magnesium chloride would be impracticably dilute; and the cost of this additional evaporation would probably balance the economy due to halving the quantity of magnesium chloride to be dealt with.

Some attention has been drawn recently to a second Austrian method of recovering sulphur from alkali waste, a method proposed by Herr Opl, of the chemical works of Hruschau, in Moravia. This gentleman proposes to mix waste with water, to treat the mixture with CO_2 and so drive off H_2S from it, and then to pass this H_2S into more mixture of waste with water, in order that it shall be absorbed by the calcium sulphide of this second quantity of waste with formation of solution of calcium sulphydrate, which could then be treated in any one of several ways. This proposal seems to me defective, for the reason, among others, that I do not see how it would be practicable to avoid sending an excess of CO_2 into the second quantity of mixture of waste and water, which excess of CO_2 would react on some of the calcium sulphydrate formed in that second quantity of such mixture, driving off H_2S, and so occasioning both loss of sulphur and nuisance. Certainly, Herr Opl's method of getting the sulphur of alkali waste into the solution as calcium sulphydrate cannot, I think, compete with the simpler method of heating the waste with water under pressure.

Here, at last, I draw this too long paper to a close. I have had to show in it that the immediate future of the English Leblanc soda industry is somewhat gloomy; but I trust that I have shown also reason to believe that sufficient attention to the complete utilization of all raw materials is yet capable of saving it.

Faure's Secondary Pile.—In Planté's battery the formation of the current is limited by the thickness of the leaden plates. Faure gives to his couples an almost unlimited power of accumulation, by covering the electrodes by a layer of spongy lead. In a pile of 75 kilogrammes he is able to store a quantity of energy sufficient to furnish a horse power for an hour.—*Comptes Rendus.* C.

Experiments upon Electric Lamps.—The French committee have reported the results of their experiments with the Jablochkoff, Debrun, and Jamin lamps, when run by the Debrun, Gramme, and Meritens dynamo machines. They find that the different lamps and machines produce economical results which are almost identical, whether measured by the amount of light furnished per horse-power or by the electric efficiency of the light.—*Comptes Rendus*, Nov. 13, 1882. C.

Optical Study of Elasticity.—Lœwy and Tresca describe an apparatus for the accurate optical measurement of the flexion that is produced in tubes and bars, and give rules for its employment in determining co-efficients of elasticity. They claim for their method three principal advantages. 1. The results obtained by different methods check one another, so as to give conclusions of great precision. 2. The apparatus is so arranged as to prevent systematic errors. 3. The values obtained vary as the square of the flexion, so that accidental errors have but a slight influence. The sensibility of the apparatus is such that the addition of a single gramme produces an effect which can be easily measured.—*Comptes Rendus*, Dec. 4, 1882. C.

Digestive Power of Papaine.—Adam Wurtz reports an experiment, in which papaine dissolved a thousand times its weight of moist fibrine, the greatest part of which was transformed into peptone, not precipitable by nitric acid and which, by means of a complete hydration of the fibrine, even formed a small quantity of a crystallizable starchy substance, such as is often observed in good pepsinic digestions. In another experiment, 0·05 gramme (0·77 grain) of the same papaine liquefied 100 grammes, or 2,000 times its own weight, of moist fibrine, with the exception of a trifling residue of dyspeptone. From these experiments he concluded that the ferment, being of an albuminoid nature, could operate on itself so as to hydrate itself. Experiments showed that this anticipation was correct. In one case, 17 grammes of fibrine were divided as fine as possible, by means of scissors, then put in contact for a few minutes, at an ordinary temperature, with a weak solution of papaine, then pressed and washed for half an hour under a strong jet of water, and then washed thoroughly with distilled water. The fibrine, after this pressure and repeated washings, was digested at 40° (104°F.) with 75 cubic centimetres of pure water. On the next day the solution was complete, with the exception of about one per cent. of dry dyspeptone.—*Comptes Rendus*.

Origin of Thermo-Electricity.—The thermo-electric batteries, and especially those of M. Clamond, had raised large expectations because the corrosion of the solderings was attributed to heat alone, and it was hoped that it might be remedied. Exner has just shown that it is due to oxidation by the air, aided by the heat; and that if this action was prevented, by the use of nitrogen, for example, the electric current would not be formed. Thermo-electric batteries are, therefore, simply gas-batteries, in which certain gaseous fluids act in a similar manner to acid liquids.—*Chron. Industr.* C.

Movements of Submerged Bodies.—In defending his hypothesis against the attacks of French academicians, Dr. Siemons refers to the experiments of Froude, at Torquay, under the direction of the English Admiralty. He arrived at the unexpected result, that a submerged body, if it moves with a uniform velocity through a perfect fluid, will encounter no resistance whatever. By a "perfect fluid" he understood a fluid free from viscosity or *quasi* solidity and in which no friction is caused by the gliding of its particles over one another or over the surface of the body. The luminiferous æther is presumably such a fluid, and the discussion of Siemen's theory cannot be settled until all the consequences of perfect fluidity are duly settled.—*Comptes Rendus*, Nov. 27, 1882. C.

Malleable Nickel.—Pure nickel, after melting and casting, generally holds a greater or less quantity of oxygen in solution and the metal is brittle. To hinder the injurious effects of the oxygen, it is necessary to incorporate in the melted nickel some substance which has a strong affinity for oxygen and also for the nickel itself. J. Garnier finds that phosphorus serves both of these purposes very satisfactorily, producing effects analogous to those of carbon in iron. If the phosphorus does not exceed $\frac{3}{10}$ of one per cent. the nickel is soft and very malleable; above this quantity the hardness increases at the expense of the malleability. Phosphorized nickel, when alloyed with copper, zinc or iron, gives results which are far superior to those that are obtained from the same nickel when not phosphorized. By means of the phosphorus, Garnier has been able to alloy nickel and iron in all proportions and always to obtain soft and malleable products. The contradictions of illustrious chemists are thus explained, some saying that such alloys were brittle, others that they were malleable; the latter had alloyed the nickel to phosphorized iron.—*Comptes Rendus.* C.

Newcastle Coal.—The Newcastle basin is now yielding an average annual product of 35,000,000 tons. The beds extend under the sea, and there has been some question as to the limiting depth at which they can be worked. Even at the most moderate estimates, it is thought that there are at least seven thousand million tons which can be readily mined, which would be enough to continue the present supply for two hundred years.—*Les Mondes*, Dec. 2, 1882. C.

Purification of Ores by Air Blast.—In the neighborhood of Genolhac there are large quantities of ochreous earth, containing some threads of galena, but in no instance does the proportion of lead exceed seven per cent. The ore is consequently very poor, but it is so abundant that attempts have been made to enrich it by the ordinary processes of washing. These attempts having failed, it occurred to the engineers to try air, which was forced through three superposed metallic cloths, with meshes of four, five and ten millimetres (·157, ·197, ·394 inches), respectively. The air, being thus perfectly divided, reaches a rectangular box, at the extremity of which a hopper distributes regularly the dried and pulverized materials which it is desired to classify. The worthless portions, being the lightest, are easily driven off by the blast; while the leaden particles, being heaviest, are carried to the bottom.—*Comptes Rendus.* C.

Objections to Siemens' Theory.—G. A. Hirn calls attention to the investigations of Henry Sainte-Claire Deville, which indicate that none of the known chemical compounds could exist at the surface of of the sun. He thinks, therefore, that the compounds that Siemens supposes to be gradually dissociated by solar radiation would be recombined at some distance from the photosphere, and that the compounds would again be dissociated before reaching the sun's surface. This act would require all the heat which had been developed by the combination, so that it would contribute nothing to the conservation of solar radiation. He agrees with Faye in thinking that an absolute material vacuum is required to secure the stability of movement which has been found by astronomers. This vacuum is at variance with the doctrine which attributes all physical phenomena to the movements and shocks of independent atoms. He thinks that the defenders of this doctrine will some time be compelled to admit the existence of some immaterial agency, such as Newton recognized in his remarkable letter to Bentley. —*Comptes Rendus*, Nov. 6, 1882. C.

Utilization of Cinders and Coal Refuse.—Noack Dollfus has prepared a valuable paper upon the preparation of beton from slag and other refuse, by the addition of about 20 per cent. of lime. By using the methods and precautions which he points out, foundation walls and superstructures of great strength and durability can be made. —*Soc. Industr. de Mullhouse.* C.

New Determination of the Mechanical Equivalent of Heat.—Prof. A. Bartoli has recently found the value of 428·4 kilogrammetres (771·12 ft. lbs.) for the mechanical equivalent of heat, by the following method. He used a steel tube into which he introduced a known quantity of mercury at a pressure accurately determined and at the temperature of freezing water. The interior diameter of the tube was so small, and the length so greatt, that the mercury, on its exit from the tube, had scarcely any velocity. Keeping the temperature of the tube at the freezing point by means of ice, he measured the quantity of ice melted and thus estimated the quantity of heat developed.—*Riv. Sci. Industr.* C.

New Theory of Gases.—A. Gouilly proposes to give to thermodynamics an experimental point of departure of a greater generality than the laws of Mariotte and Gay-Lussac. He starts from the proposition that the calorific capacities of gases under constant pressure and under constant volume, are independent of the pressure and of the volume. In order to calculate the function γ, so that $\frac{d\,Q}{\gamma}$ is an exact differential, it is not necessary to adopt the hypothesis of the perfect gaseous condition, which is now applicable to none of the known gases. It is preferable to take the gaseous property which is defined by the expression $\frac{d\,C}{d\,p} = 0$. For, while the laws of Mariotte and Gay-Lussac are not rigidly true, experiment shows, in a very precise manner, at least for hydrogen and air, that the calorific capacity under constant pressure is independent of the pressure. In admitting for gases that the two specific heats are independent of the pressure and of the temperature, we find an equation with three coefficients which represents, even for carbonic acid, the laws of compressibility and of dilatation, so that the natural gases approximate the condition defined by this equation, while they all deviate from the condition of a perfect gas.—*Soc. des Ing. Civ.*, Nov., 1882. C.

Coloring Jewelry by Galvanism.—Fr. Weil has exhibited to the French Academy various articles of jewelry, which were colored by metallic layers deposited by electro-chemical processes. The colors have a great artistic value and are very durable, resisting friction, moisture, sulphuretted hydrogen, vapors of ordinary burning gas, and the action of light. Edmond Becquerel recalled the experiments of his father, in coloring metals by means of thin layers of oxide of lead and oxide of iron. He obtained very brilliant shades of various colors, and he found that by increasing the thickness of the layers, he could effectually protect metals from rust.—*Comptes Rendus*, Nov. 20, 1882.

Motion of Sun Spots.—Spœrer, in a letter to Faye, reports the results of comparisons of his observations for twenty years, which seem to indicate a slight tendency in sun spots to move towards the equator between the parallels of 5° and 10°, and a slight tendency to move towards the poles between the parallels of 20° and 25°. Carrington and de' Rico found that the direction towards the equator predominated up to 15° of latitude, and towards the poles in higher latitudes. The tendencies were so slight that Carrington did not attach any importance to them. Faye regards these results as fatal to the hypothesis of Siemens, for if the sun is fed by an influx at the poles, he thinks that there should be a uniform tendency of the spots towards the equator in all latitudes.—*Comptes Rendus*, Dec. 4, 1882. C.

Twinkling during Auroras.—Arago, in his admirable note on Scintillation, says that at the end of the 18th century Dr. Usher remarked, that at Dublin the Northern Lights make the stars singularly undulating in telescopes, and that according to Neckers, de Saussure, and Forbes, the stars do not twinkle in Scotland unless there is an aurora visible. Montigny's observations of scintillation have coincided with many visible auroras. At each one of those coincidences the intensity of the scintillation was much greater at the moment of the aurora than on the previous evening or on the following day, when the atmospheric conditions were the same but no aurora was seen. When a magnetic perturbation is noticed at the Brussels observatory without any accompanying visible aurora, the intensity of the scintillation suddenly increases, and it is then much greater than on the previous evening or on the following day under the same atmospheric conditions, with the exception of the magnetic perturbations.—*Comptes Rendus*, Feb. 26, 1883. C.

Celestial Physics.—Before starting upon the eclipse expedition, Janssen sent a communication to the French Academy, upon problems which he is investigating. By means of the photographic revolver, he finds that the movements of the granular matter of the sun are so rapid that the appearance of any photospheric region changes at very brief intervals; sometimes the space of a second is sufficient to bring about a complete change in the form of a granular element. The velocity of the movements is extremely variable, but it is generally of the same order of magnitude as those which Lockyer has observed in the gaseous matter of solar eruptions. He has long been occupied with the study of the spectrum of water vapor, but he has been subject to frequent interruptions on account of the interference of other engagements and the difficulty of constructing the extensive apparatus which is required. He hopes soon to be able to present to the Academy a complete discussion of the spectrum, covering the whole range, from the obscure heat to the ultra-violet. The knowledge of the vapor spectrum is indispensable for determining the origin of a large portion of the telluric rays; it is equally important in the study of planetary atmospheres. In the stars it may conduct us to entirely new notions about the temperature of their atmospheres.—*Comptes Rendus*, Feb. 26, 1883. C.

THE METAL OF THE FUTURE.

[From the Report of the Secretary at the Stated Meeting held May 16, 1883.]

The technical papers for the past month or two have been full of accounts of a new process for manufacturing the metal aluminium, said to have originated in England, and by which, it is affirmed in very positive terms, the price of this metal has been reduced from $5,000 per ton to $500, or to about 25 cents per pound. I shall in the proper place subject this alleged new process of manufacture to the test of criticism, to judge of the validity of the claims made in its behalf, but first will take the opportunity of giving the subject of aluminium—the metal of clay—a general consideration,

Aluminium, the metallic basis of clay, is even more widely disseminated over the surface of the earth than iron. It is one of the constituents of the minerals feldspar and mica, of which the granites and gneisses are largely made up, and of the clays which result from the

disintegration of these rocks. It exists in considerable quantities, also, in nearly all the so-called crystalline rocks, and the silicates of alumina in various combinations form the most numerous class of minerals.

Abundant as are the ores of this metal, it is one of the most difficult to reduce. Shortly after the discovery, near the beginning of this century, by Sir Humphrey Davy, that the so-called earths, soda, potash, lime, alumina, etc., were metallic oxides, and not simple bodies, as had hitherto been supposed, and his demonstration of the fact by isolating the metals sodium and potassium with the aid of the then newly discoverd galvanic battery, repeated attempts were made also to isolate aluminium, the metal of clay, but unsuccessfully, until at length, after many failures, the efforts of Wöhler were crowned with success in the year 1817. The properties of the new metal were found to be so remarkable that the attention of chemists was at once attracted to the subject of its production; but the metal obstinately resisted all efforts to produce it in quantity until the year 1854, when St. Claire Deville solved the problem measurably, by reducing the metal from anhydrous chloride by reduction with metallic sodium. It was thought then that the successful solution of the problem of producing aluminium on the commercial scale would speedily bring about a revolution in the metallurgical world. But though nearly thirty years have elapsed since that time, aluminium is still, by reason of its high price, ranked among the more precious metals, and is consequently debarred from competition with copper, zinc, tin, iron and steel for the numerous industrial uses for which it is well adapted, by reason of its many admirable and unique qualities. What these are will appear from the following brief rehearsal:

The metal aluminium has a grayish-white color, between that of zinc and tin; it is exceedingly light, being only two and a half times heavier than water—that is, about three and a half times lighter than copper, four times lighter than silver, and nearly eight times lighter than gold. It is remarkably sonorous, giving out a very clear musical tone when struck; it is very unchangeable in the atmosphere, surpassing in this respect most of the baser metals—iron, copper, etc., and resembling the precious metals silver and gold. It is very difficultly oxidizable, nitric acid (aqua fortis), which attacks and destroys nearly all the metals with the greatest energy, having little or no action upon it, and even the white heat of the furnace only suffices to oxidize it superficially. It has a tensile strength equal to that of copper, and conducts electri-

city nearly four times better than iron. It forms alloys with many of the metals, many of which have remarkable qualities. Of these alloys, those with copper—the so-called aluminium bronzes—are the most notable, being possessed of such valuable properties that their extensive adoption in the arts is only hindered by the one circumstance of their comparatively high cost.

From the above brief *resumê* of the leading characteristics of this remarkable metal, it will be at once apparent that a wide field would at once be opened for it, in almost every department of industry, if once the problem of its cheap production were solved; and assuming the truth of the newspaper accounts respecting the alleged new process of producing it in England at 25 cents per pound, the statement that the invention would "effect important changes in the metal trade, not only in England but throughout the world," is not in the least exaggerated.

Unfortunately, however, the alleged new procedure of Mr. Webster, of Hollywood, near Birmingham, which has been the recipient of a larger share of gratuitous advertising than any other patented process that has appeared for some years, will not bear a critical investigation. The process embraces two principal elements—the preparation of an anhydrous chloride of aluminium, or of a double chloride of aluminium and sodium, by a very tedious and roundabout method; and from this chloride, the metal is subsequently obtained by the use of sodium as a reducing agent.

I was greatly interested in getting at the details of this new process. Months before anything was published concerning it, it was whispered in scientific circles in England that the problem of the cheap production of aluminium had at length been solved. Even so eminent a luminary in the metallurgical world as Sir Henry Bessemer, in an address before one of the leading British engineering bodies, foreshadowed the announcement of some remarkable discovery, and set all the scientific world agog with curiosity. At length, after some months of patient waiting, the technical journals of England announced the procedure of Mr. Webster with a grand flourish of trumpets, the American journals have taken up the refrain, and it appeared to occur to no one to subject the extravagant claims of the alleged improvement to the test of intelligent criticism. For myself, I cannot refrain from the statement that I was more than astonished that claims so grossly and palpably erroneous and exaggerated should have been permitted

to pass unchallenged in the country where they originated, and which boasts of so many eminent authorities in metallurgy.

The alleged new process is almost a literal copy of the old, time-honored method introduced and practiced in France for the past twenty years. In the only important features—namely, the production of an anhydrous chloride, and the reduction of this by means of sodium, it is absolutely the same. The only features that can be called new, relate to the method of treating the raw material some convenient and cheap aluminous substance, and after reading Mr. Webster's patent specification, I am well satisfied that those portions of the process that are new are the only portions that are worthless.

All this may seem to be unnecessarily severe upon Mr. Webster, but in explanation, I have to urge that when an inventor publishes his invention with such extravagance of statement, he must expect the most searching investigation of his claims. The utter absurdity of Mr. Webster's claim to be able to produce aluminium at a cost of £100 (about $500) per ton, which would be equal to about 25 cents per pound, will appear from the simple statement, that to reduce one pound of the metal from the chloride, requires, theoretically, very nearly three pounds of metallic sodium, and in practice nearer four pounds than three, and the cost of the sodium alone required for the reduction of a pound of the metal will be almost one dollar, if not more, to say nothing of the tedious and costly preparation of the chloride. But I have said enough. Aluminium, I am satisfied, is the coming metal, destined one day to play as prominent part in the arts of civilization, perhaps, as iron, but after raising our expectations to so exalted a pitch, Mr. Webster's much advertised solution of the problem of producing it cheaply forcibly recalls to memory, by the similarity of its descent from the sublime to the ridiculous, the old quotation: "*Parturiunt montes, nascetur ridiculus mus.*"

Artificial Filtering Stone.—K. Steinman, in *Tiefenfurt bei Görlitz*, proposes filtering plates from the following mixture:

Clay	10 parts, or	10 or	15
Levigated chalk	1	1	1
Glass sand, coarse	55	..	...
" fine	...	25	65
Ground flint	...	30	5

The ingredients are mixed thoroughly in water, moulded, and hard burnt.—*Dingler's Journal.* C.

THE DRAWING SCHOOL.

On Friday evening, May 11th, a large audience of pupils, their friends and members of the Institute assembled in the Hall to take part in the closing exercises of the Drawing School.

The exercises comprised the exhibition of several hundred drawings (mechanical, architectural and free-hand), the work of the pupils of the school, addresses by several of the officers and members, the reading of the annual report of the Director of the school, and the delivery of the diplomas to those who had satisfactorily completed a full course of study in the school.

The proceedings were opened with an appropriate address by the President of the Institute, Mr. Wm. P. Tatham. After explaining the purpose of the meeting, he spoke of the great satisfaction with which the Board of Managers regarded the present very prosperous condition of the Drawing School. This satisfaction, he said, originated not only because of the unprecedentedly large number of the pupils who attended the school during the past year, but also from the unusual excellence of their work as shown by the specimens on exhibition, which demonstrated at once the thoroughness of the instruction, the faithfulness of the teachers and the assiduity of the pupils.

The Secretary then read the report of Mr. Wm. H. Thorne, Director of the school.

Annual Report of the Director of the Drawing School of the Franklin Institute for the Sessions 1882–1883.

That the importance of some knowledge of the Art of Drawing is becoming more appreciated every year is evidenced by the annual increase in the number of students in this school. It is a promising sign, for there is no sphere, in which the ability to express conceptions of beauty of form and design, or ideas of mechanical devices and constructions, by means of lines drawn on paper in such a manner as to accurately convey these conceptions to others, will not prove of great value. The boy who attempts to make a bird-box, will save time, vexation and material, if he is able to plan it on paper, altering the design until it suits his fancy and arranging the details and method of construction before he commences the work. So the millionaire, who is about to have a mansion built, if he is able to understand the architect's plans, can criticise, suggest alterations and devise conveniences, which will place the stamp of his own individuality upon it and prove a source of just pride. To one engaged in a mechanical or industrial

pursuit, a knowledge of drawing is coming to be indispensable, and those who do not possess it will inevitably fall behind in the race. To quote from the recently published autobiography of the eminent Scotch engineer, James Nasmyth: "Mechanical drawing is the alphabet of the engineer; without it the workman is merely a hand; with it he indicates the possession of a head." It is of more or less importance in all pursuits, and that this is understood is shown by the number and the vocations of the students in our school.

The number of students this year amounted to 402, of whom 210 attended the winter term and 192 the spring term. In each term, the school was divided into seven classes with an instructor for each class, and instruction was given four evenings in the week instead of two as heretofore, on account of limited accommodations.

The progress made has been very satisfactory and that some good work has been done is shown by the examples exhibited. The interest taken in theoretical drawing is encouraging, as particular attention has been given to the thorough and correct teaching of the principles of projections and intersections and what is really Descriptive Geometry, stripped of its rules and put into a practical and modern form. Many complete Working Drawings, both Mechanical and Architectural have been made in a superior style, not after the ordinary school systems but by the methods employed in our best workshops. In the Free Hand Classes, there has been marked progress, and several of the students have made good drawings from the round. There is a great want of models, casts and appropriate accommodations in this department.

The aim has been to make the instruction practical and useful and to have the classes so graded as to insure systematic progress. The teaching includes correct manipulation, the geometry of drawing and its application to the useful arts. The instructors have had two difficulties to contend with, one of which is an indifference to accuracy and neatness of execution on the part of some of the students, while the other is the apparent inability of other students to understand the principles involved, although taking great pride in the appearance of their work. But few appreciate the importance of both a thorough understanding of the rationale of the methods employed and also of precision and beauty of execution.

The following list includes those who have shown the most talent, made the most progress and produced the best results, for which Honorable Mention is made of them:

In the Senior Mechanical Classes.—Willis H. Groat, Reinholdt Kuehln, A. M. Hahn, W. J. Bradley, Albert R. Ridgeley, J. F. Braun, Charles A. Eimert, George Eimert, John Louis, M. Morgan.

In the Intermediate Mechanical Classes.—Charles B. Scott, Edw. A. Miller, Alphonso Kirschner, James T. Baker, Jacob Weber, Wm. Levick, Henry H. Brown, Sidney Newbold, E. W. Thomas, Henry Kirst, and Fred'k O'Neill.

In the Junior Mechanical Classes.—James G. Davis, J. N. Butler, Justus Allen, William Nace, Joseph Edel.

In the Architectural Class.—George F. Jackson, A. A. Belfield, James J. Allen, Alfred Richardson, Newman Collins.

In the Free Hand Classes.—G. H. Merchant, J. J. Reutlinger, Charles Bregler, Fred'k Reutlinger, Chas. Fleming, Siegfried Kuder, Max Hindle, Wm. Winneberger, Carrie Ayres.

The following students, having completed a full course of four terms, are recommended for the award of certificates to that effect:

Willis H. Groat, Reinholdt Kuehln, Albert R. Ridgeley, W. J. Bradley, J. F. Braun, A. M. Hahn, G. H. Merchant, J. J. Reutlinger, H. S. McCaffrey, Rudolph Boericke, J. L. Taylor, Wm. B. Thompson, Clark T. Dill, C. G. Whittaker, John Fauser, George Keyser, Charles McDowell, Carroll Lukens, Wm. S. Moore, Harry Casey.

The results of the year are encouraging to the instructors and should be staisfactory to the Institute and also to the pupils, but few of whom have failed to receive benefit from their attendance. The efficiency of the school has been largely due to the ability and hearty co-operation of my assistant instructors, Messrs. Carl Barth, Edw. S. Paxson, C. Claussen, Geo. S. Willets, and Wm. P. Dallett.

Next year the school will be better prepared than ever before to meet the growing demand for practical instruction in Mechanical, Architectural and Free Hand Drawing.

WM. H. THORNE,
Director.

At the close of the reading of the report the diplomas were delivered by the President to the pupils who were entitled to receive them.

After the close of the formal exercises, brief addresses were made by Mr. Hector Orr, Mr. James Fraiser, and the Secretary. An inspection of the drawings on exhibition followed, and the gathering dispersed with the general expression of satisfaction with the work of the school.

W.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON HUGO BILGRAM'S IMPROVEMENT IN GEARING FOR METAL PLANERS.

Philadelphia, Pa., March 20, 1882.

To the Committee of Science and the Arts
of The Franklin Institute, Philadelphia.

GENTLEMEN:—Your committee appointed to examine application No. 1210, Hugo Bilgram's improvement in "gearing for metal planers," met and examined the drawing and description annexed and heard the oral explanation of Mr. Bilgram.

This is a device designed to overcome the objection of wear and lost motion in the ordinary gear for imparting reciprocating motion to the bed of metal planers.

It consists of two independent sets of gear, ingeniously arranged, upon one set of shafts and boxes—one set imparting the slow and working motion and the other the reversing or idle motion. (See detailed description attached).

Each train of gear is driven by the belt, first on the slow and forward train, thus propelling the bed while cutting; then the belt is shifted by the shifting arrangement on to the fast or returning train, and returns the bed quickly, at the same time propelling the first train in the reverse direction, the power being applied through the rack on the bed to the other end of the train. There being no cessation of contact, no points form back lash.

In like manner the reversing train is propelled in its reverse direction, so there is no lost motion or back lash arising from it.

To prevent the trains running beyond the point driven by the bed, by their momentum or that of the driving pulleys, there is placed a frictional leather washer against the sleeve of one train and the axle of the other.

As both trains move in the same direction there is no wear on this washer, indeed no motion except the slight shift that may be occasioned by much wear of the gears after long use.

Your committee are of the opinion that this device is a good and practicable arrangement for correcting the defects and overcoming the annoyance arising from lost motion in the ordinary gear of the planing machine.

HALL OF THE INSTITUTE.

November 1, 1882.

At the stated meeting of the Committee on Science and the Arts, held on above date, it was decided, on motion of Mr. Chabot, to amend the report by incorporating a recommendation for the award of the Scott Legacy Premium and Medal. As so amended the report was adopted.

H. R. HEYL,
Chairman.

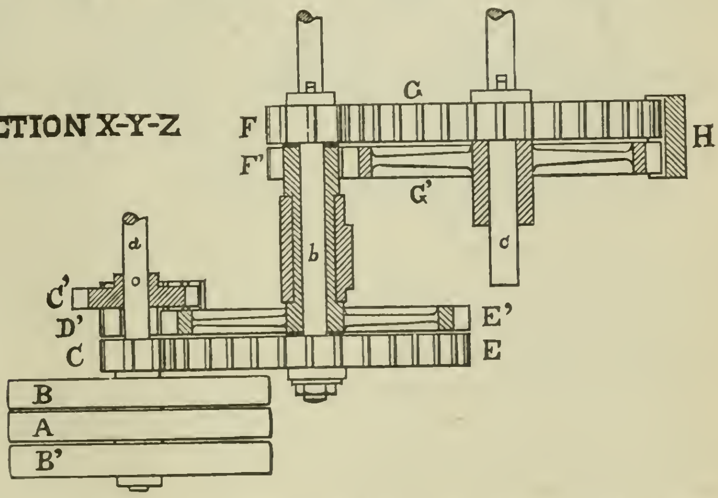
Attest: WILLIAM H. WAHL,
Secretary.

DETAILED DESCRIPTION.

The object of the invention is to obviate the jar occasioned by the back lash of the gears at the instant of reversal of the motion of the table, which is accomplished by supplying two independent trains of gears to connect the two belt pulleys with the rack of the table.

Referring to the accompanying engraving, B, A and B' represents the

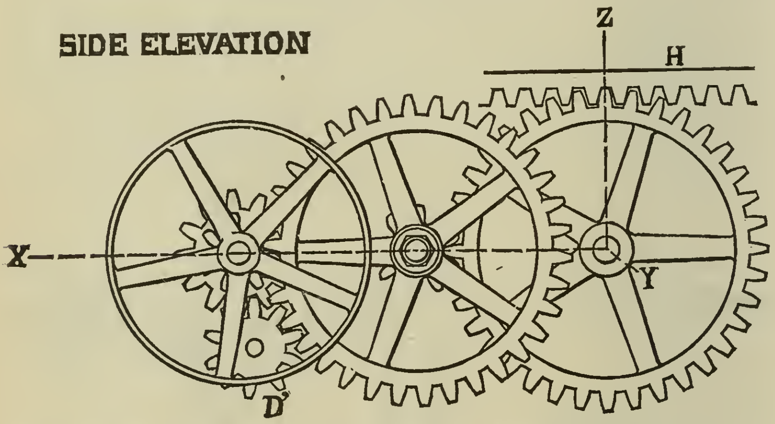
SECTION X-Y-Z



belt pulleys, of which B' is fixed to the shaft a, while the pulley B, together with the pinion C, to which it is united, is free to turn upon the shaft a. A is the loose pulley. The pinion C engages with the gear E, fastened to the shaft b, which latter carries the pinion F. Upon a third shaft c, is fixed the gear G, engaging with the rack H of the table. Upon the shaft a, is fastened a small gear wheel C'; another gear wheel D' gears both into C' and the gear wheel E'. By this gear

the reverse motion is produced, though both pulleys in their turn are run in the same direction by the belt. The gear E' is attached to one end of a sleeve e, carrying at its other end the pinion F'. This sleeve is free to turn upon the shaft b. The pinion F' engages with a wheel G', loose on the shaft c, which gears into the rack H. The machine when thus constructed is run by a single belt that may be shifted from one pully to the other.

The two pulleys B and B' are thus connected with the table by two independent trains of gears. When the belt runs on the pulley B, moving the table by the train C, E, F, G, H, the second train C', D', E', F', G', H will be moved by the rack H, whereby the teeth of the



latter train are kept in working contact so that when the belt is shifted from the pulley B to the pulley B', the train is ready for immediate action without loss of motion. The same conditions prevail when the belt is again shifted to the pulley B.

Either one of the two trains of gears when moved in one direction receives its motion from the pulley, while when moved in the opposite direction it derives its motion from the rack. For this reason the teeth of the gear wheels are constantly kept in gearing in the same sense, and hence a jar resulting from back lash is impossible.

Pressure Battery.—A. P. Zazareff has addressed a note to the French Academy relative to an electric pressure battery. The production of electricity is due to the passage of a solution of glycerine, under the action of a pressure which is more or less severe, through a mixture of coke and anthracite.—*Comptes Rendus.* C.

Franklin Institute.

Hall of the Institute, May 16th, 1883.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tathem, in the chair.

There were present 80 members.

The minutes of the last meeting were read and adopted.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held May 9th, 16 persons had been elected to membership.

The several Special Committees reported progress, and were continued.

Mr. Robert Grimshaw read a paper entitled "Comparison of Indicator Rigs," which was discussed by Mr. John W. Nystrom. An abstract of Mr. Grimshaw's paper will appear in the Journal for July.

The Secretary's report embraced a criticism of certain alleged improvements in the manufacture of aluminium; an account of recent improvements in the secondary battery; a brief account of the history and engineering features of the East River bridge, and a description of a number of inventions, among which were the following, viz.:

John G. Baker's meat chopper, designed for butchers, farmers, restaurants, etc. It consists of a hopper and cylinder combined, the latter containing the screw which carries the meat forward. A four-bladed knife is attached to the end of the screw and revolves with it as the crank is turned. A plate perforated with numerous small holes fits into the end of the cylinder and is secured in position by a ring which screws up and clasps the plate tightly against the knife.

The process is as follows: The meat is fed into the hopper and carried forward by the screw until it reaches the perforated plate, when the pressure forces it into each of the small holes in the plate, where it is chopped off by the revolving knife which makes four cuts for each hole, with every revolution of the crank, the small pieces thus cut being forced out by the continuous pressure from the interior of the cylinder.

A number of these machines of various sizes were exhibited, among them being one of large dimensions driven by power, and having a capacity of 1,000 pounds per hour.

The Rue Manufacturing Co.'s Boiler Testing Apparatus, is a combination of two instruments—the one filling the boiler, the other applying the pressure. It is designed to test boilers with warm water under

a continuous even pressure without shock or jar, which, it is affirmed, cannot be done with a pump and cold water.

The Rue Manufacturing Co.'s Boiler Testing Apparatus, is designed to dispense with the usual cold water test. The method consists in filling the boiler full of hot water (say 180° or more), then applying the required pressure by means of an injector constructed for the purpose, which also continues to add heated water to the boiler. A safety or relief valve is set to open at the pressure to which it is desired to test the boiler, and the operation of the injector is such as to accumulate and maintain that pressure constantly and as long as may be required. The apparatus consists, therefore, substantially in the arrangement of an injector and ejector especially constructed and connected for the purposes above described.

Gray's Grindstone Dressing Machine, for truing the faces of grindstones, exhibited on behalf of G. A. Gray & Co., Cincinnati, consists of a series of serrated disks placed in a gang on a rod held in a suitable fixture and brought into contact with the face of the stone to be dressed. The spurs or disks revolve independently and pick the surface instead of scraping it.

Shrieves & Cook's Chemical Underground Electrical Conduit, is made by providing troughs formed of earthenware or other material, which are placed in suitable trenches and the wires stretched therein. The filling employed is a mixture of sulphur and sand or other siliceous material, forced into successive sections of the line in a melted state. This compound is claimed to be "hard, water-proof, and indestructible," and the method is said to afford an excellent insulation, durability, economy and convenience of laying such conduits.

Neracher's Automatic Hose-reel, for mills, warehouses, railway stations, etc., was exhibited by Mr. Wm. H. Johnson. The reel is provided with a permanent connection with the water supply, and the playing out of the hose automatically turns on the water by opening the valve.

The Planetary Car Wheel of Mr. H. G. Yates, consists of a series of friction rolls upon which the axle revolves. These rolls are disposed in such a manner as to reduce friction and wear to a minimum.

Under New Business, Mr. E. Alexander Scott was accredited as a delegate to represent the Institute at the Exhibition of Railway Appliances, about to be held in Chicago. Whereupon, the meeting was adjourned.

WILLIAM H. WAHL, *Secretary.*